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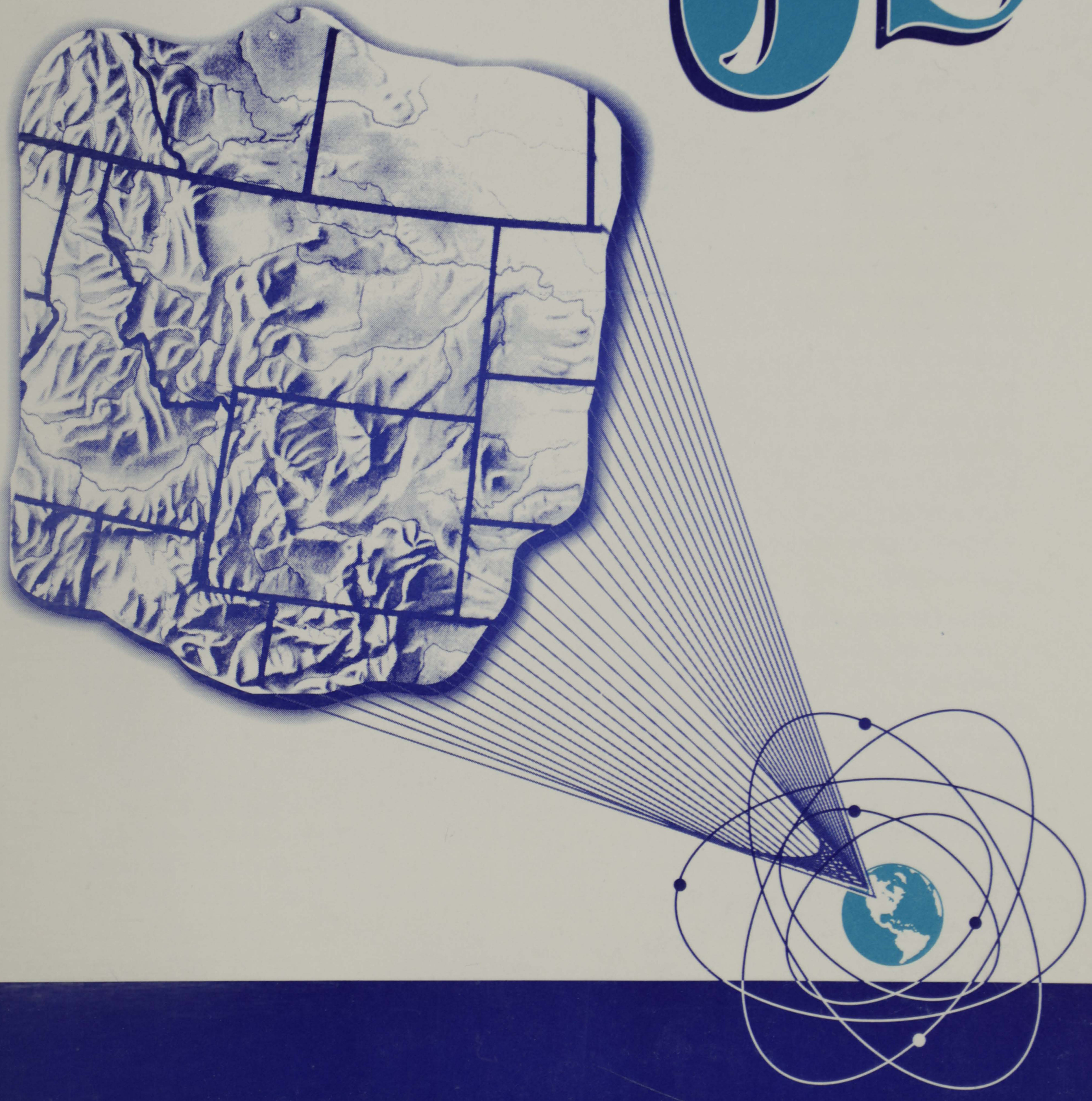

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Submissions will be peer reviewed and page charges will be calculated at the same rate as for regular articles.

Literature Cited

Dusek, Gary L. 1995. Guidelines for manuscripts submitted to the *Intermountain Journal of Sciences*. Int. J. Sci. 1(1):61-70.

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Design and Layout ~ Media Works, Bozeman, Montana

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Kristie L. Allen
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Small Mammal Capture Efficiencies Among Three Trap Types

Abstract

*Capture rates of small mammals were compared among live, pitfall, and snap traps to determine the relative efficiency of trap types by species and mammal groups. Three small mammal trap types were employed concurrently in each of 53 sites representing major vegetation types of Montana. Shrews (*Sorex *spp.), sagebrush voles (*Lemmiscus curtatus*), and northern pocket gophers (*Thomomys talpoides*) were captured more often than expected in pitfall traps. Chipmunks (*Tamias *spp.) and deer mice (*Peromyscus maniculatus*) were caught significantly more often by live traps. The capture rate for voles (*Microtus *spp.) did not differ significantly among trap types. We conclude that a combination of trap types must be used to accurately assess small mammal species composition, diversity, and abundance.*

Key Words: Montana, habitat, small mammals, capture efficiency, trapping, snap trap, pitfall trap, live trap, trap success, Rocky Mountains.

Introduction

Studies of small mammal trapping show that results depend on trapping methods (Laurance 1992, Slade *et al.* 1993). Cockrum (1947), MacLeod and Lethiecq (1963), and Williams and Braun (1983) agree that there are dangers inherent in many community composition and population studies that treat different trap types as unbiased across species. Trap efficiency also varies with season (Pucek, 1969), weather (Doucet and Bider 1974), animal size (West 1985), animal residency status (Boonstra and Krebs 1978), and odors of previous animals captured in the trap (Daly and Behrends 1984, Gurnell and Little 1992). Variation in community structure described in the literature may be partly due to differences in trapping methods.

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Differential capture rates of trap types have been demonstrated for some, but not all, small mammal species. Two to 36 times more individual shrews have been caught in pitfall traps than in snap traps, (MacLeod and Lethiecq 1963). Brown (1967) and Pucek (1969) also reported that masked shrews (*Sorex cinereus*), pygmy shrews (*S. hoyi*), and vagrant shrews (*S. vagrans*) have been captured almost entirely in pitfall traps. On the other hand, deer mice have been captured more frequently in snap traps than pitfall traps (Kalko and Handley 1993). The efficiencies of trap types in capturing species of other small mammal groups, such as voles and chipmunks, have not been reported as frequently.

Studies using trapping to determine species occurrence, density, community structure, population dynamics, and/or interspecific interaction may be seriously biased by inadequate knowledge of differential susceptibility to trapping. Thus, we compare success of pitfall, snap, and live traps in their ability to capture 19 small mammal species in Montana. *P*-values <0.20 are reported to show trends for species with small sample sizes. Six species and three genera show significant differences in capture frequency per trap type.

Methods

Fifty-three sites, originally chosen to represent major environmental types of Montana (Ross and Hunter 1976), were trapped over five summers between June 1977 and October 1982. These included two alpine sites dominated by tufted hairgrass (*Deschampsia caespitosa*); 19 forested sites: one limber pine (*Pinus flexilis*), six ponderosa pine (*Pinus ponderosa*), four Douglas fir (*Pseudotsuga menzesei*), three lodgepole pine (*Pinus contorta*), two subalpine fir (*Abies lasiocarpa*), one grand fir (*Abies grandis*), and two western redcedar (*Thuja plicata*); two riparian sites dominated with *Phalaris ariandinaria* (reed grass); 18 shrubland sites: 12 big sage (*Artemesia tridentata*), three greasewood (*Sarcobatus vermiculatus*), and one each of chokecherry (*Prunus virginianus*), creeping juniper (*Juniperus horizontalis*), and rocky mountain juniper (*Juniperus scopulorum*); and 12 grassland habitats: six needle-and-thread (*Stipa comata*), one bluebunch wheatgrass (*Agropyron spicatum*), three idaho fescue (*Festuca idahoensis*), and two little bluestem (*Andropogon scoparius*). Elevations ranged from 700 to nearly 3,900 meters. At each site, two independent traplines were run concurrently about 0.5 km apart. Each line had 25 trap stations placed at 10 m intervals. Each station included a sunken can pitfall trap (15.7 cm diameter by 17.6 cm deep), a folding Sherman live trap (7.6 x 8.9 x 22.9 cm, model LFATDG), and two standard commercial snap traps (5.0 x 10.0 x 1.6 cm) arranged in a diamond pattern with side lengths 1 m. The upper lips of the pitfall traps were flush with the ground and earth was filled in around the can. Cans contained approximately 4 cm of water to prevent shrew cannibalism and escape of captured animals. Both snap traps and live traps were baited with a peanut butter and rolled oat mixture. Trapping at each site spanned five consecutive nights, resulting in 1000 trap-nights per site. On two sites, only one trapline was run and/or fewer than five consecutive nights were trapped. For this reason captures are summarized as captures per 1000 trap nights. All mammals captured were removed.

To evaluate differences in species and mammal group capture rate by trap type, we used the nonparametric Kruskal-Wallis Test on the SAS statistical package (SAS Institute Inc. 1988). We rejected parametric analysis of variance evaluation because the data were not normally distibuted with equal variances.

Results

In approximately 52,000 trap-nights, 1398 individuals representing 25 species were captured. Six species with fewer than three captures were excluded from individual analysis but were included in the analysis of generic differences (Table 1). Vulnerability to capture varied among trap types for six of the 19 species and two of three mammal groups, shrews and chipmunks. (Table 1).

Shrews, overall, were most susceptible (*P*=0.0001) to pitfall traps, as were the two most common species, the masked (*P*=0.0002) and wandering shrews (*P*=0.02). Though they were captured too infrequently to test for significance, pygmy shrews, Merriam's shrews (*S. merriami*), and Preble's shrews (*S. preblei*) were also caught most often in pitfall traps (Table 1) .

Voles (arvicolines), as a whole, were not more easily caught in any single trap type (*P*=0.14). An exception, the sagebrush vole, was most susceptible to pitfall traps (*P*=0.05). The most abundant species, red-backed voles (*Clethrionomys gapperi*), prairie voles

Table 1. *Number caught and captures/1000 trap nights, for all small mammal species in three trap types: pitfall, live, and snap.*

No. captures	Mammal species	Live	Pitfall	Snap	*P*-value[1]
228	*Sorex* Spp. - Shrews	0 5	13.4	2.2	0.0001*
123	*S. cinereus*	0 1	6 5	1 6	0 0002*
5	*S. hoyi*		0.3		ns
3	*S. merriami*		0.2		0 1336
7	*S. preblei*		0 5		0.0663
86	*S. vagrans*	0 4	5.4	0.5	0.0216*
127	Arvicolines - Voles	2 2		2.5	0.1409
61	*Clethrionomys gapperi*	1.2	1	1.3	ns
4	*Lemmiscus curtatus*		0.3		0.0479*
5	*Microtus montanus*	0 1	0.2	0.1	ns
27	*M. ochrogaster*	0 3	0 8	0.5	ns
23	*M. pennsylvanicus*	0 6	0.6	0.3	ns
5	*Phenacomys intermedius*	0 1	0.2	0 1	ns
	Sigmodontines - Rats and Mice				
3	*Neotoma cinerea*	0 2			ns
1,009	*Peromyscus maniculatus*	39 4	4.7	17.7	0.0001*
13	*Tamias* Spp - Chipmunks	0.9		0.1	0.0027*
6	*T. amoenus*	0 5			0 0059*
4	*T. minimus*	0.2			0.1632
3	*T. ruficaudus*	0.2			ns
	Others				
11	*Perognathus fasciatus*	0 1	0.7		ns
3	*Thomomys talpoide*		0.2		0.0479*
10	*Zapus princeps*	0 2		0.2	0.1729

[1]*P*-values indicate the probability that trap efficiency does not differ among the trap types. *P*-values less than 0.20 are included to show trends, though only those below 0.05 are considered significant

(*Microtus ochrogaster*), and meadow voles (*M. pennsylvanicus*) were equally susceptible to all trap types. The montane vole (*Microtus montanus*) and heather vole (*Phenacomys intermedius*) were collected too infrequently to show significance.

Deer mice were most frequently captured with live traps (P=0.0001). Because too few were captured, no trend was demonstrated for the bushy-tailed woodrat (*Neotoma cinereus*), the only other sigmodontine caught more than twice.

Although chipmunks were rarely caught, they were captured most frequently in live traps (P=0.003) for the group as a whole. The most common chipmunk species, the yellow-pine chipmunk (*Tamias amoenus*), was most frequently caught in live traps (P=0.006). Least chipmunks (*Tamias minimus*) and red-tailed chipmunks (*T. ruficaudus*) were rare and sample sizes were too small to show significant associations.

Three pocket gophers, 10 western jumping mice (*Zapus princeps*), and 11 olive-backed pocket mice (*Perognathus fasciatus*) were caught during the study. Pocket gophers were caught only in pitfall traps (P=0.05) while western jumping mice and olive-backed pocket mice did not show a significant susceptibility to any particular trap type (P=0.17; P>0.20, respectively).

Note that species with the same number of captures may have different P-values in the analysis. Also, species with the same *P*-values after analysis have different capture numbers. This results from different variances of capture rates between species because different numbers were captured on different sites (i.e. if the number captured is three for a species, different *P*-values will result if all three were captured at a single site making the variance higher than if one specimen was taken at each of three different sites).

Discussion

Mechanistically, any number of variables could contribute to a species' susceptibility to a particular trap type. Animal size has been found to be a factor (West 1985), so animal species and age may be expected to contribute also . Other factors, like body form, dietary preferences, response to enclosure and/or foreign material also contribute to differences in susceptibility (Laurance 1992). A mammal species' lack of jumping ability, attraction to baits, or lack of trap avoidance could increase capture rates. We hypothesize mechanisms that may have produced the observed results, though this study was not designed to test the validity of those mechanisms.

Body size was seemingly the primary factor in species' predisposition to capture in pitfall traps. Pitfall traps captured the smallest individuals and non-jumping species as opposed to larger and/or more athletic species. Shrews, the smallest mammals captured in this study, and less acrobatic species, like voles and pocket gophers, were very susceptible to pitfall traps. Chipmunks, being larger than the other small mammals discussed here, could jump out of cans at will. Similarly, more agile mammals like deer and jumping mice, were not often captured by pitfall traps containing only 4 cm of water. The few deer mice caught in pitfalls were juveniles or sub-adults, which increases our confidence that animal size may be the most important factor. It has been suggested that a higher water level would increase captures of deer mice (Kirkland, unpublished data from New Mexico and Pennsylvania) by increasing the size an animal must be to reach bottom and jump out.

Live traps baited with peanut butter and oatmeal were expected to attract omnivores/granivores but not be very successful with browsers or insectivores. Chipmunks are omnivores and were captured most often in live traps. Other omnivores, deer and jumping mice, were also captured more frequently than the availability of live traps would suggest. The browsing voles were not captured more frequently in live traps than other trap types. Also, few insectivorous shrews were caught in live traps (3 percent of shrew captures), supporting the hypothesis that dietary preference plays some role in species' susceptibility to live traps.

Other studies, however, have been very successful in capturing shrews in live traps (Douglass, pers. comm. 1993) when they are the only trap type used. Live trap trigger sensitivity may also play a role in the numbers of shrew captures (Kirkland, pers. comm. 1995).

Live traps have been modified and/or specifically designed to improve measurement of densities of smaller mammals trapped poorly with the Sherman live trap we used. Modifying trigger sensitivity may increase shrew captures in Sherman live traps. The Longworth live trap, designed for mammals smaller than 4 grams, has been used successfully in England to capture shrews (Kirkland, pers. comm. 1996).

We believed snap traps would capture the same species as live traps because they also were baited. We did expect differences in capture numbers due to the smaller size of the snap trap and its less obtrusive nature than Sherman live traps. Thus, in comparison to live trap success, we expected fewer chipmunk captures, since the animal is relatively large, and increased mouse, vole, and shrew captures due to the smaller and less conspicuous nature of the snap trap. Only chipmunks and shrews conformed to our expectations. Chipmunks were caught significantly fewer times in snap traps than live traps. Shrews, overall, were caught four times more often in snap traps than in live traps. Masked shrews were caught 16 times more often in snap traps than live traps. Voles, western jumping mice, and deer mice showed no significant increase in captures over those caught in live traps.

Implications of our work for small mammal sampling are: (1) not all species present at a site may be detected in small mammal surveys, especially if all three trap types are not used, (2) biased estimates of density or presence may result from trapping with inappropriate trap types, such as using snaptraps for chipmunks or trapping shrews with too-large live traps, and (3) abundance comparisons between studies must be based on consistently collected capture/recapture data or validated indices (Kaufman *et al* 1978, Schroder 1981).

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Effect of Electroshock Voltage and Wave Form on Mortality of Incubating Walleye Eggs

Abstract

Commonly used electrofishing wave forms and voltages were tested to determine if they could be used to kill walleye eggs as part of walleye-control projects. Eggs were exposed to Pulsed DC (direct current), AC (alternating current), or Smooth DC (SDC) current from an electroshocker at outputs of 0.98, 2 6, or 5.9 v/cm, respectively, for 10 seconds. Different batches of eggs were exposed once to each of the treatments on days 1-7 post-fertilization. Eggs exposed to SDC were affected by electroshock for the first 2-3 days post-fertilization. During this period, 65-86 percent of the exposed eggs died compared to 42.6 percent of the controls.

Key words: walleye, electroshock, eggs.

Introduction

Electrofishing, a commonly used fish census technique, causes varying degrees of physical trauma to fish (Schreck *et al.* 1976, Sharber and Carothers 1988, Dalbey *et al.*1996, Snyder 1995). Electroshock can also cause mortality of trout eggs during the sensitive period of development (Dwyer *et al.* 1993). Currently, Montana Fish, Wildlife and Parks is evaluating means to control an illegally introduced walleye (*Stizostedion vitreum*) population in Canyon Ferry Reservoir. Because walleye exhibit fidelity to spawning grounds (Olson *et al.* 1978; Colby *et al.* 1979; Craig 1987), electroshock of eggs deposited in spawning areas may be a means to control recruitment.

Our objective was to define the effects of electroshock on mortality rates of walleye eggs using pulsed DC, AC, or smooth DC. We tested the hypothesis that there is no effect of electroshock on walleye egg mortality.

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Materials and Methods

Freshly fertilized eggs collected from wild fish were received from Montana Fish, Wildlife and Park's Miles City Fish Hatchery. One tablespoon of eggs, about 1700 was measured into each of 84 10.2 x 10.2 cm wire screen baskets and placed into Heath[R] Incubator trays. The eggs in the baskets were exposed to one of three treatments: pulsed DC (PDC), alternating current (AC), or Smooth DC (SDC). Baskets of eggs to be treated were removed from the incubator, gently poured from the wire screen basket into a nylon basket in the exposure tank, exposed to the current from an electroshocker for 10 seconds, and returned to the incubator. Different groups of eggs were exposed to the treatments on each day from fertilization to hatch. The controls were either handled or not handled (C-H and C-NH). The handled controls were moved from the incubator and placed into the exposure chamber in the same manner as the treated eggs but no electric current was applied; the non-handled controls were not moved from the incubator until termination of the experiment. The measured output of the shocker was 0.98, 2.6, or 5.9 v/cm, for PDC, AC, and SDC, respectively (Table 1). All treatments were in triplicate.

A 208 X 55 X 49 cm Living Stream[R] fiberglass tank was used as an exposure chamber. The electrodes were 47.0 X 55.9 cm pieces of sheet metal secured near each end of the chamber. Electrodes were 104.1 cm apart and parallel; the surface of the electrodes covered the entire cross sectional area of the tank. The electroshocker control box was connected to this configuration, producing a homogeneous electrical field.

The output of the electroshocker control box was monitored and electrode characteristics recorded in addition to water conductivity and temperature. The output average was

Table 1. *Electroshock characteristics as measured by an oscilloscope and a voltage meter by treatment (PDC = pulsed dc, AC = alternating current, and SDC = smooth dc).*

		Treatment	
Parameter	PDC	AC	SDC
		60 hz	
Mean voltage[a]	255	255	500
Peak voltage[b]	310	360	500
Voltage gradient[c]	0.98	2.6	5.9
Amps[d]	1.9	1.5	2.5

[a] Measured with an in-line voltage meter.
[b] Measured with an oscilloscope directly at the electrodes.
[c] Voltage gradient (vg) measured with a vg probe and the digital volt meter in v/cm. This is an average measurement.
[d] As measured by the amperage meter on the electroshocker control box.

Table 2. *Mean percent walleye electroshock egg mortality rates by day and treatment.*

					Treatment					
Day	PDC[a]		AC[b]		SDC[c]		C-NH[d]		C-H[e]	
1	40.7	(9.5)[f]			86.0	(12.2)	41.6	(2.6)		
2	50.4	(5.1)	42.1	(2.8)	73.6	(10.7)			42.6	(2.1)
3	38.9	(7.2)	42.5	(2.2)	64.9	(13.0)	39.6	(4.6)		
4	42.9	(2.1)	42.9	(2.7)	52.1	(5.9)			48.9	(5.3)
5	49.1	(5.4)	42.7	(1.2)	44.7	(2.9)	39.2	(4.6)		
6	45.0	(3.6)	50.9	(12.3)	40.2	(3.5)			44.9	(2.3)
7	40.0	(3.3)	42.7	(2.0)	38.8	(5.2)	39.3	(0.6)		

[a] pulsed direct current
[b] alternating current
[c] smooth direct current
[d] control (not handled)
[e] control (handled)
[f] standard deviations are shown in parentheses

measured with a digital volt meter and peak voltages were measured with an oscilloscope. Current was also recorded from the meter on the control box. The average voltage gradient in the water was measured with a digital volt meter.

The tests were terminated after seven days when the eggs were eyed and near hatching. Eggs were preserved in 10 percent formalin and evaluated by counting the living and dead eggs. Percent mortality was determined and recorded for each treatment.

The data were analyzed using the NCSS 6.08 one-way ANOVA (Hintze 1995).

Results and Discussion

Only the eggs exposed to SDC during the first 2-3 days post-fertilization, were killed at the voltages used in this test (Table 2). Mean percent mortality of the eggs exposed to the SDC treatment were 86.0, 73.6, 64.9, and 52.1 percent on days 1, 2, 3, and 4 post fertilization. Mortality of the eggs exposed to SDC on days 1, 2, and 3 were significantly higher (alpha = 0.05) than the 42.6 percent mean mortality of the eggs from the handled control treatments on day 2. Smooth DC caused more mortality to cutthroat trout eggs than 30 or 60 Hz pulsed DC at similar voltage levels (Dwyer and Erdahl 1995). Perhaps the higher voltage alone is the main cause for the increased mortality of walleye eggs as was demonstrated with cutthroat trout eggs (Dwyer *et al*. 1993).

Percent mortality of the eggs exposed to the 60 Hz pulsed DC and the AC treatments did not differ significantly from the handled control (C-H) treatment. Mortality ranged from 38.9 - 50.4 percent and 42.1 - 50.9 percent in the PDC and AC treatments, respectively, and 42.6 - 48.9 percent in the handled controls..

Use of electroshock to reduce walleye egg survival in large water bodies such as Canyon Ferry Reservoir may not be feasible because of the considerable effort needed to shock spawning areas repeatedly during brief periods when eggs are sensitive to electroshock. If there is potential for this technique, it will probably require using higher voltage equipment and dragging electrodes on the bottom, putting the electric field where the eggs are and avoiding non-target fish such as trout.

Acknowledgments

We thank Mike Rhodes and his staff for supplying the walleye eggs; the effort and hours spent counting eggs by Scott Travis Opitz is sincerely appreciated.

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Aquatic Macroinvertebrates in Young Beaver Ponds on a Small Prairie Stream, Wyoming

Wayne A. Hubert
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Abstract

We describe aquatic macroinvertebrates in 10 beaver ponds less than 10 years old on a small prairie stream in southwestern Wyoming. A greater diversity of taxa were obtained from sweep net samples through the water column than from Ekman dredge samples of the bottom substrate. Densities of benthic macroinvertebrates did not differ significantly among the 10 ponds, but the mean density was relatively low compared to values reported for beaver ponds studied in woodland and montane systems. Aquatic macroinvertebrate densities may be low in beaver ponds on prairie streams due to the relatively small amounts of leaf litter that accumulate in ponds and the frequent destruction of ponds by floods.

Key Words: macroinvertebrates, benthos, ponds, beaver, *Castor canadensis*, Great Plains, Wyoming.

Ponds constructed by beaver (*Castor canadensis*) on streams are important components of both woodland and prairie ecosystems, but there is limited information on the aquatic macroinvertebrates that inhabit beaver ponds. Previous studies on macroinvertebrates in beaver ponds have focused on woodland (Keiper 1966, Naiman *et al*. 1986, McDowell and Naiman 1986) or montane (Gard 1961, Hodkinson 1975a and 1975b, Smith *et al*. 1991) stream systems. We know of no studies of aquatic macroinvertebrates in beaver ponds on small prairie streams on the Great Plains.

Much of the previous research on aquatic macroinvertebrates in stream systems with beaver ponds has focused on comparisons of the structure and function of macroinvertebrate assemblages in beaver ponds and unimpounded stream reaches (McDowell and Naiman 1986, Naiman *et al*. 1986, Smith *et al*. 1991) or the effect of ecological succession of beaver ponds on macroinvertebrates assemblages in the ponds (Keiper 1966, Hodkinson 1975a and 1975b). No studies are known to us that evaluate variation in benthic macroinvertebrate densities among beaver ponds of similar age within a complex of ponds. A complex of beaver ponds is usually composed of a primary pond built to impound water around a lodge and to cover the winter food cache, as well as several secondary ponds built to improve transportation of food and extend the swimming range of beaver (Grasse and Putnam 1955).

The purpose of this study was to describe aquatic macroinvertebrates in a complex of young beaver ponds (< 10 years old) on a small prairie stream on the Great Plains in southwestern Wyoming. We evaluated differences in aquatic macroinvertebrate densities in

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benthic samples among the 10 ponds and described the relative abundance of aquatic macroinvertebrates in sweep net samples through the water column and in benthic samples.

Study Area

The study was conducted on Crow Creek, Laramie County, Wyoming, where it flows onto F. E. Warren Air Force Base near the City of Cheyenne. A complex of 10 ponds with an active colony of beaver was present at this location. The ponds had no stream segments with water flowing in the original stream channel between them and they were long and narrow (< 10 m wetted width) with water extending across the high-water stream channel. Surface area of the ponds ranged from 40 to 1,190 m^2 with maximum water depths of 0.6-1.2 m during late summer. The ponds were constructed in the mid-1980s following a severe flood and were 8-10 years old when sampled. Bottom substrates were primarily sand with some areas of silt and fine gravel. The ponds were colonized by aquatic macrophytes, primarily *Chara*, *Carex*, *Potomogeton*, and *Scirpus*. Minnows (Cyprinidae) and suckers (Catostomidae) were present in the stream and ponds. The riparian zone was dominated by willows (*Salix*), which were the dominant material used in construction of the dams.

Discharge in the stream channel immediately downstream from the complex of ponds was 0.0083 m^3/second on August 10, 1993. Discharge during spring and summer occasionally exceeds 1.0 m^3/s when melting snow or thunderstorms enhance flow. The beaver ponds were at about 1,880 m above mean sea level.

Methods

Sampling was conducted on August 10, 1993. Four samples of benthic macroinvertebrates were taken from each pond with an Ekman dredge (23 x 23 cm), one on each side of the pond in water less than 0.5 m deep and one at each end in the deepest locations. Two samples were taken with a 0.2-m-diameter sweep net (363 um openings) passed along the bottom of each pond in water less than 0.5 m deep and through any aquatic vegetation that may have been present. Samples were preserved in formalin and returned to the laboratory where macroinvertebrates were removed from debris with the aid of a dissecting microscope. Mollusks and insects of the orders Ephemeroptera, Plecoptera, Trichoptera, and Odonata were identified to species when possible, while other macroinvertebrates were identified to family or genus.

Mean densities of the 13 most abundant taxa of benthic macroinvertebrates were assessed among the 10 study ponds for samples taken with the Ekman dredge. We recognized that a multivariate analysis of variance (MANOVA) could be used to assess differences in mean densities among ponds, but interpretation of significant differences with a large number of variables (taxa) is difficult and we were not interested in relations among different taxa (Bray and Maxwell 1985). A one-way analysis of variance was used to assess differences in mean densities of each abundant taxon among the 10 ponds. The Bonferroni pairwise comparison of means was used to make comparisons among ponds if significance was determined with ANOVA. Statistical analyses were conducted using STATISTIX 4.1 (Analytical Software 1994). Significance was determined at $P < 0.05$ for all tests.

Results

The most abundant macroinvertebrate taxa in bottom substrate sampled with the Ekman dredge were Oligochaeta, Chironomidae, *Pisidium compressum* and Pulmonata (Table 1). The most

Table 1. *Proportions (percent) of aquatic macroinvertebrate taxa in samples from beaver ponds on a Great Plains stream during August 1993 using two different sampling methods.*

Taxa	Ekman dredge	Sweep net
Ephemeroptera		
Tricorythodes minutus		1.4
Baetis tricaudatus		0.2
Trichoptera		
Hydroptila sp.		0.3
Odonata		
Aeshna palmata		0.1
Amphiagrion sp		0.2
Argia sp		0.1
Coenagrion sp.		3.3
Diptera		
Chironomidae	31.5	13.1
Ceratopogonidae		0.1
Chrysops sp.	0.6	0.5
Coleoptera		
Dubiraphia sp	2.0	2.1
Hemiptera		
Corisella sp.		1.3
Collembola		
Isotomidae		0.2
Amphipoda		
Hyallela azteca	2.3	21.7
Decapoda		
Orconectes neglectus		0.4
Hirudinea	0.3	0.1
Oligochaeta		
Naididae	41.0	3.5
Turbullaria		
Tricladida	0.1	
Pulmonata		
Physa gyrina	0.9	7.1
Gyraulus parvus	0.1	2.1
Helisoma anceps	5.2	10.0
Ferrissia rivularis	2.1	0.3
Bivalvia		
Pisidium compressum	13.6	27.2
Anodontoides ferrusacianus	0.3	

Table 2. *Densities (number/square meter) of benthic macroinvertebrates in samples taken with an Ekman dredge from beaver ponds on a Great Plains stream during August 1993.*

Taxa	Mean	Standard error
Chironomidae	391.1*	57.9
Chrysops	7.3	4.1
Dubiraphia	24.8	6.1
Hyallela azteca	28.5	21.9
Hirudinea	4.2	2.7
Nadidae	508.0	166.2
Tricladida	1.2	1.2
Physa gyrina	11.4	5.0
Gyraulus parvus	1.2	0.8
Helisoma anceps	63.8	17.0
Ferrissia rivulari	25.3	10.3
Pisidium compressum	167.8	40.7
Anodontoides ferrusacianus	3.6	2.0
TOTAL	1,238.2	227.0

* significant difference ($P < 0.05$) in mean densities among the 10 study ponds

numerous organisms in sweep net samples were *Pisidium compressum*, *Hyallela azteca*, Pulmonata, and Chironomidae. Sweep net samples had a greater diversity of organisms than did Ekman dredge samples (Table 1). Most insect taxa were found exclusively in sweep net samples, with the exception of Chironomidae, Tabanidae, and *Dubiraphia*.

The mean density of all macroinvertebrate taxa among the 10 ponds in samples taken with the Ekman dredge was 1,238/m². Densities of individual taxa did not differ significantly among the 10 beaver ponds (Table 2), with the exception of Chironomidae ($P < 0.0001$). The fourth pond in progression downstream had a significantly higher density (mean = 1,205/m²) of Chironomidae than the other nine ponds (mean = 344/m²).

Discussion

The greater diversity of aquatic macroinvertebrates found in samples taken with the sweep net was likely a result of the sweep net sampling a more diverse array of microhabitats (water column, aquatic vegetation and surface of bottom substrate) than the Ekman dredge. Numerous studies have shown a greater diversity of aquatic macroinvertebrates among aquatic macrophytes than in bottom substrates of lakes and streams (Gilinsky 1984, Gregg and Rose 1985, Schramm and Jirka 1989, Wollheim 1994).

Longitudinal trends in abundance and diversity of aquatic macroinvertebrates were not observed among the 10 ponds in the complex that we studied. We noted that sand dominated the substrate in samples from all 10 ponds with no observable change with downstream progression. Previous studies have demonstrated substantial variation in both abundance and diversity of benthic macroinvertebrates associated with different sizes of particles composing bottom substrate (Cummins and Lauff 1969, Ward 1975, Hubert et al. 1984). The relatively homogeneous bottom substrates among the ponds probably contributed to the lack of significant variation in benthic macroinvertebrate densities among ponds.

The mean density of benthic macroinvertebrates in these Great Plains beaver ponds (mean = 1,238/m^2) was far less than has been observed in beaver ponds on small woodland streams in Quebec (24,000-72,700/m^2, McDowell and Naiman 1986) or on a montane stream in California (21,300/m^2, Gard 1961). Crow Creek was bordered by prairie with occasional patches of willow. It is likely that there is substantially less leaf litter in this prairie system and, consequently, lower food resources for aquatic macroinvertebrates than in woodland or montane streams (Minshall 1988, Naiman et al. 1988).

The macroinvertebrates in these prairie beaver ponds were composed of an array of functional feeding groups (Cummins 1973, Cummins and Klug 1979) dominated by collectors, scrapers, and predators with few shredders. Shredders use decomposing vascular plant material or coarse particulate organic matter primarily, and such material may be sparse in the prairie system. McDowell and Naiman (1986) also noted a lack of shredders in the beaver ponds they studied.

The dynamics of beaver ponds on prairie streams are likely to differ from woodland and montane systems. The ponds that we studied were relatively young (8-10 years), small (< 1.1 ha surface area), narrow (< 10 m wetted width), and on a creek that experiences large variation in discharge (frequently > 100 fold). Such beaver ponds are common among prairie streams of the Great Plains. It is likely that the aging of beaver ponds on Great Plains streams leads to accumulation of silt and fine particulate matter with faunal succession (Kieper 1966, Hodkinson 1975a and 1975b). However, long-term succession may be truncated by more frequent pond destruction than in woodland or montane systems due to the small-diameter building materials, willow branches, used in dam construction and wide fluctuations in discharge, especially associated with summer thunderstorms.

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Impacts of Cattle Grazing on Mesic Grizzly Bear Habitat Along the East Front of the Rocky Mountains, Montana

Abstract

During the summers of 1985 and 1986, we measured vegetation characteristics to determine impacts of cattle grazing on cover and forage preferred by grizzlies within aspen and willow plant communities along the East Front of the Rocky Mountains in north-central Montana. Information collected on the phenology of bear foods growing in aspen and willow stands revealed that the more nutritious bear foods produced seeds late in the growing season. The utilization of bear foods by cattle in five study pastures showed that in 6 weeks all herbaceous bear foods were >40 percent utilized. Although sites protected from cattle grazing for 2 to 10 years had more aspen and willow suckers than did grazed sites, grazed sites appeared to be recruiting enough shoots for stand survival. Hiding cover for bears tended to be higher in ungrazed than grazed sites and in sites grazed in months other than June than in sites grazed in June. Deferring grazing in pastures with willow and aspen stands until 1 July and removing cattle from pastures when 50 percent of herbaceous forage in mesic communities was eaten would minimize short term impacts of cattle on plant species preferred by grizzlies. Long term management systems could be designed to encourage or discourage grizzly use of pastures by implementing livestock rotation systems that influenced seed production and standing crop of phenologically desirable growth stages of food plants and cover value of other plants.

Key words: Grizzly bear, *Ursus arctos*, habitat, grazing.

Introduction

Studies on the East Front of the Rocky Mountains of Montana have produced a large data set on grizzly bear (*Ursus arctos horribilis*) habitat use, movements, and distribution (Schallenberger and Jonkel 1978, 1979, 1980; Aune and Stivers 1981, 1982, 1983; Aune *et al*. 1984; Aune 1985; Aune *et al*. 1986; and Aune and Brannon 1987). Approximately 65 percent of spring and early summer grizzly range in this area is managed primarily for the production of livestock forage. Cattle account for 89 percent of livestock grazing. During spring and early summer, cattle and grizzly bears show considerable overlap in diet and habitat use because they use common riparian plant communities (Aune 1985).

Although many researchers believe that livestock grazing can have negative impacts on grizzly bear habitat (Mealey *et al*. 1977, Schallenberger and Jonkel 1980, Sizemore 1980, Knight *et al*. 1981, Aune and Stivers 1982), no data were available to assess the impacts of grazing on vegetation composition, phenology, and/or the structure of riparian communities favored by bears along the East Front. This study was initiated to gather these data.

Study Area

The study area encompassed 600

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km² in Teton and Pondera counties in the foothills of the Rocky Mountains and adjacent prairie (Fig. 1.). Land ownership was divided among the U.S. Forest Service (USFS), Bureau of Land Management (BLM), Montana Fish, Wildlife, and Parks (MFWP), The Nature Conservancy, the Boone and Crockett Club's Theodore Roosevelt Memorial Ranch, and private individuals. Federal agencies controlled access to approximately 5 percent of the study area, MFWP approximately 6 percent, private conservation groups approximately 8 percent, and private landowners approximately 80 percent. The dominant land uses were cattle ranching and recreation. The area had been subjected to extensive oil and gas exploration since the 1950's, but few wells were in production at the time of the study.

Elevations in the study area ranged from 1340 to 2070 m. Annual precipitation averaged 30 cm at low elevations and approximately 50 cm at high elevations (Stivers 1988). Temperatures ranged from -40 to 32° C annually. The average growing season was 90 days. Strong westerly to southwesterly winds were common.

Vegetation varied with landscape position. Along streams, the dominant plant communities consisted of aspen (*Populus tremuloides*), cottonwood (*P. trichocarpa*) and willow (*Salix* spp.). The prairie and higher elevation grasslands were dominated by bluebunch wheatgrass / Idaho fescue (*Agropyron spicatum / Festuca idahoensis*) and shrubby cinquefoil / rough fescue (*Potentilla fruticosa /F. scabrella*) habitat types. Stands of subalpine fir (*Abies lasiocarpa*), Douglas fir (*Psuedotsuga menziesii*), lodgepole pine (*Pinus contorta*), limber pine (*P. flexilis*), and Engelmann spruce (*Picea engelmannii*) were common at higher elevations and/ or on wetter slopes of foothills. Detailed descriptions of the vegetation and habitat types are given by Harvey (1980), Kasworm (1981), and Lesica (1982). Vegetation communities occupying study sites were classified into cover-types based on the plant species dominating the primary and secondary canopy strata. Plant identification followed Hitchcock and Cronquist (1973).

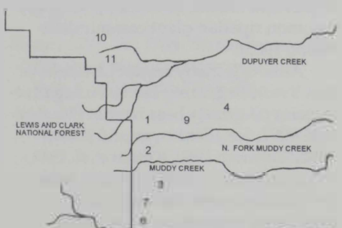

Figure 1. *Map of the East Front study area showing major features and locations of sites used in paired vegetation comparisons.*

Methods

During 1979-85, the senior author worked with Charles Jonkel and Keith Aune on grizzly bear studies conducted along the East Front. Sites selected for paired comparisons, cattle utilization comparisons, and plant phenology descriptions were identified based on this experience.

Paired sites

We selected sites used in paired comparisons on the bases of similarity in vegetation communities, seral stages, slope, topography, aspect and elevation; and marked differences in grazing regimes. We categorized grazing regimes into 5 types: Grazed (G = pastures grazed in several months between May and October); Ungrazed (U = pastures that had been rested for at least 1 year prior to May 1985); Late Grazed (LG = pastures in which grazing was deferred until after 1 July); Early

Grazed (EG = pastures in which cattle were grazed in late spring and/or early summer but were moved by 1 July); and Winter Grazed (WG = pastures in which cattle were held for supplemental winter feeding during several months between November and May). Both current and historic grazing regimes were considered when selecting stands, and sites comprising pairs were in the same or adjacent drainages with grazing regimes separated only by fences. All paired sites in aspen stands were in the same clones

Three randomly located points were identified in each site in each pair (Stivers 1988) and marked with a 100-cm steel pin to aid in relocation. A 20-m transect was established at each pin. On a randomly chosen side of each transect, a 20 x 3-m rectangular plot was delineated. Deviations from random placement were made only to insure that plots did not overlap or fall on vegetation ecotones.

Estimates of bare soil were made in 40 50-cm² microplots at 0.5 m intervals along each transect. We also recorded all vegetation, alive or dead, that intercepted a tape stretched along each transect in a plane 0.5 to 1.0 m above the ground as an index to the lateral coverage a stand would provide for a walking or sleeping bear. The index was calculated by dividing the total millimeters intercepted by plant material by 60,000 millimeters available on the 3 transects at each site.

Overhead canopy coverage, an index to the shade provided by a stand, was estimated using a vertical viewing tube (Emlen 1967). The tube had a field of vision of approximately 1 m² at a distance of 3 m above the tube. Canopy coverage was measured as the percent of the viewed field covered by vegetation. Nine readings were taken at 1 m above the ground at each sampling site.

The 60 m² plot marked at each sampling site was used to obtain information on abundance, species composition, and size distribution of vegetation. The taller shrubs (species capable of growing to heights > 2.0 m) and all trees in each 60-m² plot were counted and placed in height (0-1, 1-2, and >2m) categories by species. Percent canopy coverage by height category (0 - 0.5, 0.5-1, and 1-2 m) was estimated for small shrubs (species incapable of growing to heights >2 m).

For herbaceous species considered desirable bear foods (Aune and Stivers 1981, 1982, 1983), canopy coverages of small species were estimated as a percentage of each 60-m² plot; stems of the larger forb species were counted; and the average heights of species in both groups were recorded. An examination of data collected in the first half of the 1985 field season indicated that variation in herbaceous vegetation within plots was as great as variation among plots in the same stand so the 60-m² plots were subdivided into 15 m² units for measurement of herbaceous vegetation during the second half of the 1985 field season and throughout the 1986 field season.

Although riparian sites within pairs were similar except for grazing treatment, different pairs varied extensively in vegetative character and placement in the landscape. They also differed greatly in current and past land use. We were unable to locate appropriate, independent replicates necessary for conventional statistical analyses. Logistical constraints (limited personnel, the need for sampling all sites within a narrow time window, difficulty in relocating sample points in dense vegetation, and problems with obtaining permission to sample some private lands) and our desire to minimize the number of unexpected confrontations with bears also limited the number of sites included in the study.

Because sampling problems precluded most conventional parametric, multi-treatment, and multivariable approaches to analysis of differences between individual paired sites, we used the Wilcoxon signed-rank test (Zar 1984) to compare median values between groups of sites. Stivers (1988) used Student's t-tests and 2x2 contingency tests (Zar 1984) to explore differences between sites within pairs based on values obtained from the three 60-m^2 plots, 12 15-m^2 subplots, and three 20-m transects per site. This approach had low power to detect differences between paired sites and introduced the possibility of pseudo-replication in some tests, but it did eliminate extraneous variation in tests due to a heterogeneous landscape. This approach also allowed us to identify threshold values for differences in vegetative characteristics that we use in this paper. Most t-tests that were significant in Stiver's (1988) exploratory analyses involved differences between sites of ≥100 percent (high value minus low value divided by low value x 100) in variables measured by counting stems or estimating canopy coverage. "Differences" noted in data related to paired sites that we present in this paper are based on this threshold.

The grazing regimes in effect in 1985 and 1986 at many of the sites did not represent historic regimes, and measurements based on our system of pairing may not have reflected historic impacts of grazing on individual stands. We did not have the resources to identify and measure an independent set of sites to investigate long term changes in vegetation associated with grazing, but we did have access to information on pasture fencing patterns (which determine the landscape arrangements that constrain cattle use patterns), stocking rates, and grazing timing on paired sites dating from the 1950's. We used this information to assess the relationship between variables we thought might reflect changes in vegetation that could influence use of stands by grizzly bears that would occur over several decades of grazing (numbers of perennial forbs in the family Umbelliferae, numbers of trees and tall shrubs <2 m in height, percent ground coverage of common herbaceous plants used by bears, and canopy coverage of shrubs 0-1 m in height). We used measurements of vegetation at paired sites in 1986, a year when all transects were measured after canopy coverage had reached near maximum closure, to compare these variables with the number of years pastures had been released from grazing, historic stocking density, and the proportion of pasture in aspen and/ or willow stands using Spearman rank correlations (Zar 1984). Preliminary assessments of some stands indicated that bear foods might be most vulnerable to cattle grazing during late spring and early summer so we also contrasted pastures in which summer grazing had been historically deferred until after 1 July with those pastures in which grazing did occur in June using Mann-Whitney rank-sum tests (Zar 1984).

Pasture utilization by cattle

Pastures included in tests of cattle utilization patterns were selected based on the proportion of the pasture covered by riparian vegetation, the cattle grazing system in effect during 1985-86, and the willingness of land managers to allow us access to land they controlled. In order to determine short term impacts of cattle grazing on bear foods in mesic plant communities, five pastures were chosen that differed in size, shape, relief, proportions of mesic communities, timing of livestock use, stocking density, and age classes of livestock. We used these pastures to determine the association between cattle utilization of mesic tree communities (and associated bear foods) and two variables related to grazing patterns: 1) the amount of time cattle were in the pasture: and 2) the distance of mesic tree stands from the gates where cattle entered the pasture.

In each pasture, sample points were chosen in mesic vegetation at 200-m intervals from the gate cattle entered the pasture. At each point, 20 x 3-m plots were established following the procedures described for paired sites. The measurements taken at each plot were also the same, except that microplots and line intercepts were not employed. Vegetation measurements were made 1 week before cattle were put in the pasture and at 2 to 3-week intervals while cattle were present.

To determine the extent to which cattle utilized bear foods, two indices of bear food biomass were calculated for each plot. The first biomass index was calculated by multiplying the number of stems of species of bear foods in the family Umbelliferae [sharptooth angelica (*Angelica arguta*), cow-parsnip (*Heraculem lanatum*), mountain sweet-cicely (*Osmorhiza chilensis*), and western sweet-cicely (*O. occidentalis*)] by the average height per plant. The second index was calculated by multiplying the canopy coverages of three other categories of herbaceous plants used extensively by bears [grasses/sedges, common dandelion (*Taraxacum officinale*), and clovers (primarily *Trifolium longipes*)] by the average height of plants in each category in the plot. Utilization was estimated by comparing the change in biomass-index values between measurements. Values were expressed as the percentage of the maximum estimated biomass for each plot. Differences between sampling periods were assumed to represent a combination of increases of plant biomass due to growth minus biomass removed by grazing and/or trampling. Mean utilization values for each grazing interval were calculated based on values for individual pastures in both years. The association between the length of time cattle grazing occurred and the residual biomass was tested using Spearman's rank correlations.

To determine if mesic sites close to the entrance gate were utilized more than distant sites, utilization plots were grouped into 0.2-km categories based on plot distances from the gate cattle entered the pasture. The percentage of maximum estimated biomass left at the end of the grazing period was then averaged for all pastures and compared by distance categories. The association between the distance from the gate cattle entered and the residual biomass at the end of the grazing period was tested using Spearman's rank correlations.

Bear food phenology

Plant phenology descriptions were based on information collected at paired stands, pastures measured for cattle utilization patterns, and sites with concentrations of specific species of plants heavily utilized by bears. Information on plant phenology was used to construct a time sequence for phenological stages of important bear food plants. The phenological categories we used were: 1) new leaves; 2) flower bud; 3) flowering; 4) fruit/seed set; 5) fruit/seed ripe (fully swollen); 6) fruit/seed dry and shedding; 7) fruit/seed shed; and 8) plant dry and brown. The ranges of dates at which bear foods were in the "seed ripe" phenological stage were recorded for 1985 and 1986. Survival to this stage was deemed necessary for long term survival of the plant species.

Results

Paired contrast sites

Site characteristics. — Fifteen sites were established and measured in 1985 (Table 1). During 1986, the original 15 sites were remeasured and an additional six were established and measured. From these 21 sites, 15 paired site comparisons and two 3-site comparisons were made to examine differences attributable to cattle grazing.

Table 1. *Site characteristics and characteristics of the pastures in which sites were located for paired sites measured in the East Front study area, 1985-86.*

	Site characteristics				Pasture characteristics			
Site code[a]	Cover Type[b]	Elevation (m)	Aspect	Slope (%)	Prior years rest	Stocking density[c] (AU/ha)	Aspen and willow coverage in pasture (%)	Historic grazing period[d]
1U	Aspen-snowberry	1576	90	7	5	0.3	10	Jun 1-Sep 30
1G	Aspen-snowberry	1580	90	7	0	0.4	25	Jul 15-Sep 15
2U	Aspen-snowberry	1567	70	3	5	0.3	10	Jun 1-Sep 30
2G	Aspen-snowberry	1614	70	3	0	0.1	17	Jul 1-Sep 1
3U	Aspen-willow	1494	35	2	5	1.5	6	Sep 15-Oct 31
3G	Aspen-willow	1497	35	2	0	0.5 or 1.1	1	Jun or Aug 1-Oct 15
4U	Willow-cowparsnip	1402	120	1	2	2.2	10	Sep 5-Mar 1
4EG	Willow-cowparsnip	1408	120	1	0	1.3	19	Nov and Feb 15-May 15
4WG	Willow-cowparsnip	1381	120	1	0	3.2	26	Jan 1-Mar 31
6U	Aspen-forb	1858	135	4	2	0.6	7	Jul, Aug or Sep 1-20[e]
6G	Aspen-forb	1858	135	4	1	0.6	5	Jul, Aug or Sep 1-20[e]
7U	Aspen-forb	1896	145	4	7	0.6	1	Jul, Aug or Sep 1-20[e]
7G	Aspen-forb	1892	145	3	0	0.6	0.5	Jul, Aug or Sep 1-20[e]
8U	Aspen-forb	1593	40	9	9	0.3	7	Jun 7-Sep 1
8G	Aspen-forb	1598	40	9	0	0.4	4	Jun 15-Aug 15
9LG	Willow-forb	1512	85	3	0	0.4	25	Jul 15-Sep 15
9EG	Willow-forb	1518	85	4	0	0.6	12	Jun 1-Jul 15
10LG	Aspen-forb	1451	57	9	0	0.4	23	Aug 15-Oct 15
10EG	Aspen-forb	1451	57	7	0	0.3	18	Jun 1-Jul 31
11LG	Aspen-willow	1498	33	6	0	0.5	26	Jul, Aug or Sep[f]
11EG	Aspen-willow	1495	33	6	0	0.3	18	Jun 1-Jul 31

[a] Ungrazed (U = pastures rested for one or more years prior to measurements), grazed (G = grazed during most or all of summer 1985-86), early grazed (EG = grazed during late winter - early summer in 1985-86), late grazed (LG = grazed during late summer and/or autumn during 1985-86), and winter grazed (WG = grazed during the winter prior to measurement in 1985-86).

[b] Overstory dominated by Aspen (*Populus tremuloides*) or willow (*Salix* spp.) - understory dominated by snowberry (*Symphoricarpus albus*), willow, cow parsnip (*Heracleum lanata*), or mixed forb species.

[c] Based on the area of the pasture minus steep slopes and stands of closed coniferous forest with animal units (AU = 1 cow and 1 unweaned calf for the length of the grazing season) averaged since 1950.

[d] Dominant grazing system in effect from 1950 - 1985 or up to date of rest.

[e] A 4 pasture rest-rotation system since 1974; prior grazing season was approximately Jul 1 - Sep 15.

[f] A 3 pasture rotation system.

In 1985, most measurements were made in May and June. In 1986, most sites were measured in June and July. Remeasurements of sites sampled in both years were timed to sample stands at different phenological phases. All measurements in grazed pastures were made prior to use of new growth at sites by cattle.

Aspen dominated the upper canopy stratum at 16 sites and willow in five (Table 1). Sites ranged in elevation from 1381 to 1896 meters. Slopes were between 1 percent and 9 percent, and most aspects were easterly (33 - 145°). Seven of the sites had not been grazed for 2 to 9 years prior to 1985. Of these, one site (8U) was on the MFWP Ear Mountain Wildlife Management Area, three (1U, 2U, and 3U) were on the MFWP Blackleaf Wildlife Management Area, two (6U and 7U) were within BLM cattle exclosures, and one (4U) had been rested by a private landowner.

Cattle stocking densities ranged from 0.1 to 1.1 animal units per hectare (A.U./ha) on grazed pastures and had historically been 0.3 to 2.2 A.U./ha on pastures protected from cattle grazing. Those sites in pastures with the highest stocking densities were in winter pastures where cattle were fed hay (4U, 4EG, and 4LG) or in pastures with a fall grazing period of short duration (3U and 3G) (Table 1).

The current, or historic, grazing periods of pastures containing study sites were: eight pastures grazed during the month of June (1U, 2U, 3G, 8U, 8G, 9EG, 10EG, and 11EG), eight pastures with summer grazing (1G, 2G, 6U, 6G, 7U, 7G, 9LG, and 11LG), four pastures with fall / winter grazing (3U, 3G, 10LG, and 4U), one winter pasture (4WG), and one late winter / early spring pasture (4EG). The proportion of each pasture covered by aspen and willow communities ranged from 0.5 to 26 percent (Table 1).

Measurements for short term effects. — The 1985 and 1986 microplot measurements (Table 2) indicated that ungrazed and late grazed (grazing deferred until after 1 July) sites had less bare ground (median = 2 percent) than sites grazed in June (grazed and early grazed median = 7 percent) (signed-rank test, $P < 0.01$). Eight grazed and early grazed sites of the 15 paired comparisons had ≥100 percent more bare ground than the ungrazed or late grazed site with which they were paired. The winter grazed site had less bare ground than the early grazed and ungrazed sites with which it was contrasted.

Ungrazed sites and late grazed sites had a higher median (6 percent) for the lateral coverage index than the grazed and early grazed sites with which they were paired (4 percent) (signed-rank test, n = 15, $P = 0.03$). Five of the 12 ungrazed sites had lateral cover index values ≥100 percent higher than the sites with which they were paired, and two of the three late grazed sites had lateral cover index values ≥100 percent higher than the early grazed sites with which they were paired. Lateral coverage in the comparison of winter grazed, ungrazed, and early grazed sites did not exhibit any clear pattern (Table 2).

No consistent differences in overhead canopy coverage were apparent in the sites we sampled (Table 2). A Wilcoxon signed-rank test comparing ungrazed and late grazed with grazed and early grazed failed to reject the null hypothesis (n = 15, $P = 0.25$), and all differences between paired sites were <100 percent of the lower value.

Aspen and willow were the dominant overstory species at all sites. Douglas fir, lodgepole pine, Engelmann spruce, and limber pine were present at six sites but made up < 2 percent of the total stem count. Water birch (*Betula occidentalis*), red-osier dogwood (*Cornus stolonifera*), and common chokecherry (*Prunus virginiana*) were present in small amounts and varying combinations at

Table 2. *The 1985-1986 plot cover measurements.*

Site	Cover type	Sample date	Bare ground (%)	Lateral cover index (%)	Tree canopy coverage (%)	Trees and tall shrubs (stems per height class)			Low shrubs (% cover by height class)	
						0-1m	1-2m	>2 m	0-1m	1-2m
1U[a]	Aspen - snowberry	04/28/85	<1	<1	7	6	33	64	18	0
1G		04/28/85	0	1	7	<1*	7*	38	4*	0
1U		07/26/86	1	17	56	7	26	61	59	1
1G		07/22/86	1	13	49	4	7*	36	25*	<1
2U	Aspen - snowberry	05/08/85	0*	1	4	77	101	59	7	<1
2G		05/07/85	2	1	4	24*	24*	31	5	<1
2U		06/26/86	<1	13	53	43	59	56	37	0
2G		06/19/86	<1	5*	62	26	19*	33	40	0
3U	Aspen - willow	05/14/85	0*	6	20	59	17	28	1	<1
3G		05/15/85	7	2*	14	16*	5*	31	1	<1
3U		06/24/86	7	21	56	13*	17	25	16	2
3G		06/22/86	9	6*	56	31	22	28	9	<1*
4U[a]	Willow-cowparsnip	05/17/85	12	5*	17	68	22	37	1	<1
4EG		05/21/85	13	7	27	12*	5*	45	1	0
4WG		05/25/85	6*	10	29	2*	4*	20*	1	0
4U		07/10/86	14	47	54	19	24	35	11	1
4EG		07/09/86	17	37	61	18	22	41	1*	<1
4WG		07/11/86	1*	65	64	<1*	1*	13*	3*	1
6U	Aspen - forb	06/15/85	0	2	31	77	19	23	1*	0
6G		06/12/85	0	1*	23	34*	4*	12	2	0
6U		07/30/86	0	6	58	105	17	18	1*	0
6G		07/28/86	0	2*	45	101	3*	14	2	0
7U	Aspen-forb	06/19/85	4*	2	25	95	1*	20	1	0
7G		06/19/85	13	3	28	20*	2	33	1	0
7U		08/01/86	5*	5	50	116	1*	18	11	0
7G		07/31/86	14	6	55	92	2	31	2*	0
8U[a]	Aspen - forb	08/21/85	6*	8	42	25	16	13	7*	0
8G		08/19/85	26	7	46	17	9	11	18	0
8U		06/16/86	2*	10	45	19	17	13	12	0
8G		06/17/86	14	6	43	24	9	11	23	<1
9LG	Willow - forb	05/25/86	10*	4	15	3*	31	34	16	0
9EG		05.26.86	23	6	20	7	31	52	7*	0
10LG	Aspen - forb	06/11/86	2*	28	25	4*	2	12	10*	0
10EG		06/02/86	14	<1*	17	11	1*	10	31	0

Table 2. *(Continued)*

Site	Cover type	Sample date	Bare ground (%)	Lateral cover index (%)	Tree canopy coverage (%)	Trees and tall shrubs (stems per height class) 0-1m	1-2m	>2 m	Lowshrubs (% cover by height class) 0-1m	1-2m
11LG	Aspen - willow	06/10/86	4	4	48	38	11	36	22	<1
11EG		06/09/86	3	2*	36	54	3*	30	25	0

[a] U = pastures rested for one or more years prior to measurements; G = pastures grazing during most or all of summer in 1985-86; EG = pastures grazed during late winter - early summer in 1985-86); LG = pastures grazed during late summer and/or autumn during 1985-86. WG = pastures grazed during winter in 1985-86).
[b] Mean percent bare ground (calculated from 120 50-cm² microplots per site).
[c] Percent lateral coverage (sum of millimeters intercepted by vegetation in a plane ≤50 cm above the ground along 3 20-m transects per site divided by 60,000 mm sampled multiplied by 100).
[d] Percent overhead canopy coverage (calculated from 27 viewing tube readings per site), and mean number of stems (calculated from 3 60-m² plots per site) by height categories for trees (>98 percent *Populus tremuloides* and *Salix* spp.) and tall shrubs (predominantly *Betula occidentalis*, *Cornus stolonifera*, and *Prunus virginiana*) and for low shrubs (predominantly *Ribes* spp., *Rosa* spp., *Rubus idaeus*, and *Symphoricarpus albus*) recorded at paired contrast sites in the East Front study area in 1985-86.
* Difference in paired comparison ≥100 percent (high value minus low value divided by low value multiplied by 100).

sites 3U, 3G, 4U, 4EG, and 4WG.

Sites protected from cattle grazing usually had more aspen and/or willow stems in the 0-1 m (ungrazed median = 51, grazed median = 24; signed-rank test: n = 12, $P = 0.03$) and 1-2 m (ungrazed median = 17, grazed median = 7; signed-rank test: n = 12, $P = 0.01$) height classes but not in the >2 m height class (ungrazed median = 21, grazed median = 31; signed-rank test: n = 12, $P = 0.20$). In 2 of 3 comparisons of the 0-1 m height class in late grazed sites versus early grazed sites, the early grazed sites had >100 percent more stems per 60-m² than did late grazed sites. In comparisons of the 1-2 m and >2 m height classes, late grazed sites followed the same pattern as ungrazed sites (Table 3). The winter grazed site had fewer stems in plots in all height categories than either the early grazed or ungrazed sites with which it was contrasted.

Fifteen species of shrubs with low (< 2 m) growth forms were identified in plots during the study. The 4 shrubs most often encountered were currant (*Ribes* spp.), rose (*Rosa woodsii*), red raspberry (*Rubus idaeus*), and common snowberry (*Symphoricarpos albus*) (Table3). Snowberry had the highest average canopy cover over all sampled sites (7.1 percent canopy coverage and present in 76 percent of site samples). Rose had a mean canopy coverage of 2.1 percent and was present in 86 percent of site samples. Currant had a mean canopy coverage of 1.6 percent and was present in 94 percent of site samples. Raspberry had a mean canopy coverage of 1.5 percent and was present in 28 percent of site samples. All other low shrub species had overall mean canopy coverages of <1 percent and were present in <25 percent of site samples.

Comparisons of canopy coverage in ungrazed and late grazed sites versus paired grazed and early grazed sites indicated no differences in canopy coverage of low shrubs in the 0-1 m height class (signed rank test, n = 15, $P = 0.89$). Differences in canopy coverage of >100 percent between ungrazed and late grazed sites and the grazed or late

Table 3. *Mean numbers of stems (N) or percent canopy coverage (percent) for herbaceous bear foods[a] in three 60-m² plots at paired contrast sites in the East Front study area, 1985-86.*

Site	Date	Sharp-tooth angelica N	Cow-parsnip N	*Osmorhiza* spp. N	Mountain sweet-cicely N	Western sweet-cicely N	Glacier lily N	Strawberry percent	Grass percent	Dandelion percent	Clover percent
1U[b]	04/28/85		0*	71				<1	<1*	<1*	0
1G	04/28/85		16	132				<1	5	5	<1
1U	07/26/86	0*	0*		9	195*		<1	4*	<1*	0
1G	07/22/86	9	69		7	443		1	23	8	<1
2U	05/08/85			8*			0*	<1	<1	<1	
2G	05/07/85			34			98	<1	<1	<1	
2U	06/26/86				75	20*	0*	1*	<1*	<1	
2G	06/19/86				82	253	14	4	3	1	
3U	05/14/85	188	13	50			65	<1	5	3	<1
3G	05/15/85	2*	0*	26			0*	<1	1*	3	<1
3U	06/24/86	306	30		201*			<1	10	2	<1*
3G	06/22/86	6*	0*		405			<1	7	3	2
4U[b]	05/17/85	0	328*	15*				<1	11	<1	<1
4EG	05/21/85	<1	731	14*				<1	3*	1	0
4WG	05/25/85	0	487	155				<1	1*	<1	0
4U	07/10/86		490		10*			0	18	<1*	<1
4EG	07/09/86		594		30*			1	11	2	<1
4WG	07/11/86		726		160			<1	3*	<1*	0
6U	06/15/85				558	6*	97	1*	11	11	8*
6G	06/12/85				58*	12	34*	6	10	16	24
6U	07/30/86				179	22		5	24	12	3*
6G	07/28/86				65*	5*		2*	17	20	11
7U	06/19/85		0		1247		293	7	6	10	
7G	06/19/85		1*		1025		317	1*	7	13	
7U	08/01/86		0		483			4	18	9	
7G	07/31/86		<1		401			<1*	20	8	
8U[b]	08/21/85				77		<1	<1	24	2*	
8G	08/19/85				124		<1	<1	13	5	
8U	06/16/86				151*			1	24	6	
8G	06/17/86				339			<1	16	7	
9LG	05/25/86	143	0		94			<1	17	9	<1
9EG	05.26.86	0*	58*		86			<1	8*	8	<1

Table 3. *(continued)*

Site	Date	Sharp-tooth angelica N	Cow-parsnip N	*Osmorhiza* spp. N	Mountain sweet-cicely N	Western sweet-cicely N	Glacier lily N	Strawberry percent	Grass percent	Dande-lion percent	Clover percent
10LG	06/11/86		243		25*	1198		<1	23	1*	
10EG	06/02/86		11*		70	549*		<1	7*	15	
11LG	06/10/86	95	38		186	126		<1*	20	16	1
11EG	06/09/86	0*	1*		353	34*		3	12	11	1

[a] Plant species routinely utilized by bears (Aune and Stivers 1981, 1982, 1983): sharptooth angelica (*Angelica arguta*), cow-parsnip (*Heracleum lanatum*), *Osmorhiza* spp. (immature plants that could not be identified at the species level), mountain sweet-cicely (*O. chilensis*), western sweet-cicely (*O occidentalis*), glacier lily (*Erythronium grandiflorum*), strawberry (*Frageria virginiana*), grass (all grass and sedge species with *Poa pratense* the most common), dandelion (*Taraxacum officinale*), and clover (predominantly *Trifolium longipes*).
[b] U = pastures rested for one or more years prior to measurements; G = pastures grazing during most or all of summer in 1985-86; EG = pastures grazed during late winter - early summer in 1985-86); LG = pastures grazed during late summer and/or autumn during 1985-86: WG = pastures grazed during winter in 1985-86).
* Difference in paired comparison ≥100 percent (high value minus low value divided by low value multiplied by 100).

grazed sites with which they were paired occurred in eight of 15 comparisons, but in four comparisons the ungrazed/late grazed site had higher canopy coverage and in four it had lower values. No obvious pattern was observed in the contrast between the winter grazed site and associated ungrazed and early grazed sites. Too few sites had shrubs in the 1-2 m height class to support a signed-rank test.

For summed stem counts of five forb species used as food by bears, no consistent pattern was evident in paired comparisons of ungrazed/late grazed and grazed/early grazed sites (signed-rank test, n = 15, $P = 0.42$) or for contrasts involving the winter grazed site. Three, sharptooth angelica, cow-parsnip, and western sweet-cicely, were considered highly desirable food for bears. Two, glacier lily (*Erythronium grandiflorum*) and mountain sweet-cicely, were eaten but were not regarded as highly as food species. Only cow-parsnip and mountain sweet-cicely occurred in enough plots for Wilcoxon tests, and neither test indicated significant differences (n=15, $P = >0.10$) among medians for ungrazed/late grazed sites versus the grazed/early grazed sites with which they were paired.

For paired comparisons with ≥100 percent differences, stem counts for angelica were higher at ungrazed sites than at grazed sites in two of three comparisons, and counts were higher at late grazed than early grazed sites in both pairs where angelica occurred. Cow-parsnip stem counts were higher at grazed sites than ungrazed sites in four paired comparisons and higher at ungrazed sites than grazed sites in three paired comparisons. Stem counts in late grazed sites were higher than in early grazed sites in two of the three pairs where it occurred. Western sweet-cicely stem counts were >100 percent higher in plots at grazed sites than at ungrazed sites in three of four pairs and higher in late grazed than early grazed sites in both pairs where it occurred. Mountain sweet-cicely was more abundant in two of three ungrazed sites and two of two late grazed sites than in the sites with which they were paired. Glacier lily was more abundant in two of four grazed sites than in paired ungrazed sites and did not occur in any of the sites where we contrasted late versus early grazing.

Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*) and smooth brome (*Bromus inermis*) were the dominant species in the "grass" category. This category had the highest coverage of the 4 groups of herbaceous bear foods we measured using canopy coverage (Table 3). Grazed and ungrazed sites were not significantly different for the strawberry and grass categories (signed-rank test, n = 12, $P >$ 0.67). Grazed sides had higher median coverage of dandelions (6 percent) than did ungrazed sites (2.5 percent) with which they were paired (signed-rank test, n = 12, $P = 0.01$). Clover coverage did not occur at enough sites to support a Wilcoxon test. Late grazed sites generally had higher grass coverage than early grazed sites. The winter grazed site had lower grass coverage than the ungrazed and early grazed sites with which it was contrasted.

Measurements for long term effects — Years without cattle grazing for 21 sites measured in 1986 varied from 0 - 10 (Table 1). Spearman rank correlations indicated a significant, but weak, negative relationship between number of years of rest and the number of preferred umbel stems (angelica, cow-parsnip, and western sweet-cicely) counted in plots ($R_s = -0.38$, $P = 0.09$). Associations with percent coverage of grasses, dandelions, and clover, numbers of overstory species < 2 m in height and percent canopy coverage of low shrubs were not significant ($R_s =$ 0.05 to 0.32, $P > 0.10$).

Historic stocking rates in pastures associated with sites varied from 0.1 - 3.2 AU per ha. The only significant rank correlation with this variable was a negative association ($R_s = -0.75$, $P <$ 0.01) with percent low shrub canopy coverage. Associations between stocking rates and other variables ranged from - 0.07 to 0.17 ($P > 0.10$).

Numbers of preferred umbels were positively associated ($R_s = 0.77$, $P < 0.01$) and numbers of stems of trees and tall growth-form shrubs in the 0-1 m height class were negatively associated with ($R_s = -0.63$, $P < 0.01$) the proportion of deciduous tree coverage in the pasture. Associations between mesic deciduous tree community coverage and other variables ranged from - 0.08 to 0.21 ($P >$ 0.10).

Twelve sites measured in paired comparisons were in pastures historically deferred from grazing in June (1G, 2G, 3U, 4U, 4WG, 6U, 6G, 7U, 7G, 9LG, 10LG, and 11LG). Eight sites were located in pastures that had been historically grazed in June (1U, 2U, 3G, 8U, 8G, 9EG, 10EG, 11EG). One site (4EG), not grazed in June but frequently grazed in February through mid May, did not fit well in either category and was not included in tests.

The median number of preferred umbel stems (angelica, cow-parsnip, and western sweet-cicely) in 60-m² plots in pastures with little or no June grazing was 256. The median for pastures historically grazed in June was 28. A Mann-Whitney rank test did not indicate the medians were different ($P =$ 0.18). This test was heavily influenced by two outliers. Sites 7U and 7G were the only deferred stands with <5 umbel stems per plot. When these stands were deleted from the test, medians were significantly different ($P = 0.046$).

The median percent canopy coverage of staple herbaceous bear foods (grasses, strawberry plants, dandelions, and clover) in 60-m² plots in deferred pastures was 28 percent. The median in pastures historically grazed in June was 20 percent. This difference was not significant (Mann-Whitney rank-test $P = 0.18$), but the test was influenced by at least 1 outlier. Exclusion of site 4WG raised the median for deferred pastures slightly, but produced a significant summed rank score (sum of ranks = 144, $P = 0.048$).

Median values for the number of stems of canopy species in plots (0-1 m height class: deferred = 22, non-deferred = 22 stems, rank-test $P = 0.94$; 1-2 m height class: deferred = 9, non-deferred = 19, rank-test $P = 0.23$) were not significantly different. The median percent canopy coverage of low growth-form shrubs also did not differ between historically deferred and non-deferred sites (deferred = 11, non-deferred = 24, rank-test $P = 0.11$). Outliers did not influence these tests.

Pasture utilization by cattle

Five pastures were measured to determine short term impacts of cattle grazing on herbaceous bear foods in mesic communities (Table 4). The Kurt Heinrich (KH) and North Cow Creek (NC) pastures were measured in 1985, the Tom Salansky (TS) and Hightower (HT) pastures in 1986, and the South Dupuyer Creek (SD) pasture in both years. These pastures varied in shape, physiography (from relatively flat grassland with shallow coulees to steep foothills), abundance of aspen and willow communities (from 4 - 15 percent

Table 4. *Characteristics of five pastures in which cattle utilization patterns in deciduous tree communities were monitored in the East Front study area, 1985-86.*

	Pasture				
	KH	NC	SD	TS	HT
Year	1985	1985	1985-86	1986	1986
Plots/pasture (#)	10	10	10	3	5
Range of plot distances from gate (km)	0.8-1.6	0.2-1.2	0.2-2.0	1.4-1.8	0.4-1.6
Pasture physiography	prairie and gentle foothills	prairie and shallow coulees	gentle to steep foothills	gently rolling prairie	gentle to steep foothills
Proportion of pasture in aspen and willow (percent)	13	12	15	4	4
Pasture area (ha)	259	259	324	66	222
Class of livestock	yearling heifer	cow/calf	cow/calf	yearling heifer	cow/calf
Stocking density (A.U./ha)	0.6	1.0	0.5	0.6	0.4
Period grazed	Jun 10 - Jul10	Jun 6 - Jul 5	Jun 25 - Aug 21 ul 1 - Aug 17	Jun 1 - Sep 30	May18 - Aug 1

of surface area), and size (from 66 to 324 ha). The number of plots in each pasture ranged from three to 10 and was roughly proportionate to the amount of aspen and willow present. The distances of plots from the gate through which cattle entered the pasture varied from 0.2 to 2.0 km. Black angus or crossbreed black angus yearlings or cow/calf pairs grazed the study pastures. Stocking densities were 0.4 to 1.0 A.U./ha. All pastures were grazed for at least a 30-day period between 1 June and 30 September. The earliest entry date was 18 May, and the latest was 1 July (Table 4).

Cattle utilization of two categories of bear foods, (1) grasses/sedges, common dandelion, and clover and 2) Umbelliferae (including sharptooth angelica, cow-parsnip, and mountain and western sweet-cicely) varied widely among pastures, but the median decline in biomass was >40 percent for both categories after 6 weeks of grazing, and 80 percent or more of preferred Umbelliferae biomass had disappeared after 9 weeks of grazing (Fig. 2). In pastures where cattle were kept for 3 months or more, approximately 80 percent of the biomass of grasses, sedges, dandelions, and clovers was removed after 12 weeks of grazing. Spearman rank correlations indicated a significant negative relationship between days of grazing and residual

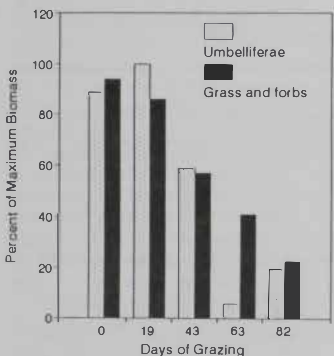

Figure 2. *Estimated median residual biomass (percent of maximum) of Umbelliferae species (angelica, cow—parsnip, and sweet-cicely) and grasses and forbs (predominantly Kentucky bluegrasses, timothy, smooth brome, clovers, and dandelion) in 5 pastures at 5 intervals during the summer grazing seasons of 1985 and 1986 in the East Front study area. The biomass index was calculated by multiplying the average height of plants by numbers of stems (umbels) or canopy coverage (grasses and small forbs) in 60-m² plots.*

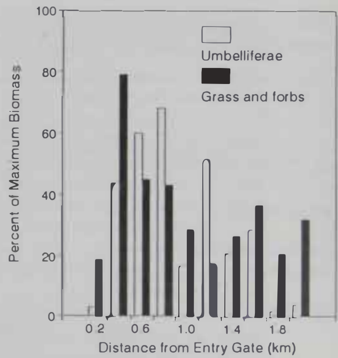

Figure 3. *Estimated median residual biomass (percent of maximum) of Umbelliferae species (angelica, cow—parsnip, and sweet-cicely) and grasses and forbs (predominantly Kentucky bluegrasses, timothy, smooth brome, clovers, and dandelion) by distance from the gate at which cattle entered at the end of the grazing season in 5 pastures during the summer grazing seasons of 1985 and 1986 in the East Front study area. The biomass index was calculated by multiplying the average height of plants by numbers of stems (umbels) or canopy coverage (grasses and small forbs) in 60-m² plots.*

biomass of umbels (R_s = -0.63, n = 23, P < 0.01) and the grass-forb category (R_s = -0.46, n = 23, P = 0.03).

We did not identify a significant relationship between distance of a deciduous tree stand from the gate at which cattle entered and utilization of preferred umbels (R_s = -0.23, n = 48, P = 0.12) or the grass-forb category (R_s = -0.08, n = 48, P = 0.60). Cattle tended to spread quickly throughout the pasture in which they were released. The median residual biomass at the end of the grazing period at sites 200 m from the entry gate was similar to or lower than medians for sites 1.8 - 2.0 km from entry gates (Fig. 3).

Bear food phenology

Seven bear foods were analyzed for earliest and latest dates at the "seed ripe" stage (Fig.4). The earliest plant species to produce seeds was common dandelion (19 May). Next were clover, the grasses (primarily Kentucky bluegrass, smooth brome, and timothy), and mountain sweet-cicely, which produced seeds in early June. Later were western sweet-cicely (15 June), cow-parsnip (25 June), and sharptooth angelica (14 July). Survival to this stage was deemed necessary for long term survival of the plant species.

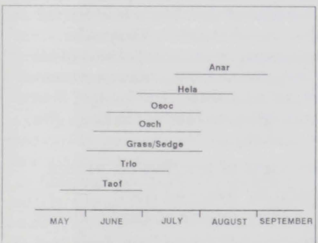

Figure 4. *Earliest and latest observed dates at which bear foods reached the "seed ripe" phenological stage in the East Front study area, 1985-86.*

Discussion

Impacts of grazing on willow and aspen communities

Grizzly bears within the study area use aspen and willow stands in significantly higher proportions than their availability would suggest (Aune 1985). These stands provide dense lateral cover that creates a secure place for bears to rest and forage. The overhead canopy provides shade on warm summer days. Willow and aspen stands growing along stream courses often form contiguous riparian corridors. These corridors provide hiding cover and resting sites for bears as they exploit foods available in prairie habitat types and during spring searches for winter-killed wild ungulates and the dead cattle annually available in boneyards of ranches (Aune and Brannon 1987). Cattle grazing has the potential to alter cover value.

The aspen literature from the Central Rocky Mountains suggests that once a mature stand is established, regeneration is minor until the stand is cut or destroyed by fire or other natural agents (Smith *et al.* 1972, DeByle and Winokur 1985). After disturbance, even-aged shoots from roots grow quickly and enough can usually survive cattle grazing to regenerate the stand if the total area of the stand is large enough (Smith *et al.* 1972, Mueggler and Bartos 1977).

In uneven-aged aspen stands, regeneration is usually sparse and the shoots grow slowly. Cattle grazing can inhibit stand regeneration under these conditions (Krebill 1972, Beetle 1974). Shoot production and stand regeneration are also influenced by carbohydrate reserves, hormonal growth promotors in the roots, genotype, and nongenetic factors such as clone history, stem age, and environmental factors at the site (Tew 1970, Schier and Johnston 1971, Jones 1975, Schier 1975 and 1981, Schier and

Campbell 1980).

In the East Front study area, aspen appears to be a climax species. The aspen parklands of Canada extend southward into northern Montana along the east slope of the Rocky Mountains (Lynch 1955). Unlike aspen of the Central Rocky Mountains, the climax aspen parklands of Canada are expanding in the absence of fire (Moss 1932, Bailey and Wroe 1974).

The data collected in this study suggested that ungrazed sites produced more aspen and willow shoots that survived the growing season, had less bare ground, more hiding cover at 0 - 0.5 m above the ground, and fewer dandelions than grazed sites. We did not find consistent short term differences in grazed and ungrazed sites in overhead canopy, canopy of low growth-form shrubs, numbers of tree stems >2 m in height, or abundance of herbaceous species. Sites grazed after June tended to resemble ungrazed sites, and sites grazed only during May and June shared many characteristics of sites grazed for the whole growing season.

Long term impacts of grazing could not be measured directly, but we were able to determine the association between historic management of pastures and some stand characteristics. Resting pastures up to 10 years evidently had little impact on stand structure, but heavy historic stocking rates may have lead to declines in canopy coverage of low shrubs. Fencing patterns that resulted in high percentages of deciduous tree stands in pastures were associated with low numbers of 0-1 m height deciduous tree species and greater abundance of some large Umbelliferae species. Deferring grazing until July on summer grazed pastures apparently impacted the species composition of the herbaceous ground stratum in deciduous communities but had no consistent impact on the structure of tree and shrub strata.

Vulnerability to damage by cattle varied among and within stands. Understory conditions in stands open to grazing varied from almost no living vegetation, to dense carpets of aspen shoots, to dense herbaceous vegetation which may have adversely affected tree shoots, but most grazed sites had aspen or willow shoots in the 1-2 m height class that had survived previous years of grazing. Impacts of cattle on stands to which they had access were not uniform. Cattle generally had preferred places for loafing and tended to feed and trample shoots most heavily in these localized areas. No sites were observed where remnant aspen or willow stands had been displaced by coniferous, shrub, or grassland plant communities. The majority of aspen and willow stands within the study area appeared to be stable in size or expanding, and bears were observed in or near all of the pastures included in the study (Aune and Stivers 1981, 1982, 1983, Aune 1985) suggesting that the range of stand conditions we observed in grazed pastures did not preclude use by bears.

Factors not measured in this study may have affected habitat security more than the vegetation characteristics we measured. Aune (1985) showed that grizzly bears avoided aspen and willow sites located close to roads (0-500 m). Bear use of any site is likely to be influenced by the juxtaposition of other plant communities, tradition, memory of past disturbance and food availability, and current food availability.

Impacts of grazing on plants used by bears as food

During spring and early summer, deciduous tree communities are important sources of succulent vegetation used by grizzly bears for food (Aune and Brannon 1987). Counts of stems of five large forb species regularly utilized by bears during spring and cattle during any part of the growing season did not vary consistently between grazed and ungrazed or late grazed and early grazed sites. Comparisons for individual species of highly preferred Umbelliferae in individual paired sites did suggest that resting pastures or deferring summer grazing until at least 1 July might favor angelica.

Sites that had been rested for several years or had historically low stocking rates and sites in pastures with abundant deciduous tree cover had a greater number of preferred umbels than heavily stocked sites in pastures with low deciduous tree cover. Sites that had been grazed during June, since the 1950's, tended to have lower numbers of stems of one or more of the three species of preferred umbels than sites that had not been grazed in June. Pastures traditionally grazed in early spring (4U, 4EG, and 4WG) had high stem counts for cow-parsnip.

Deferring grazing until July or later (through management or because of the time required for cattle to reach interior areas in large aspen or willow stands) would presumably allow some individuals of species which produce mature seeds in July and August, such as angelica, cow-parsnip, and western sweet-cicely, to complete seed production before cattle reached them. Plants consumed by cattle in June would not likely have time to produce a new seed crop before the first killing frosts in September, but plants subjected to early - mid spring cattle grazing followed by summer rest would have time to produce seeds.

Although bears actively seek large umbels, a large part of the diet of grizzly bears in spring and early summer along the East Front consists of "staples" such as grass, strawberry plants, dandelions, and clover (Aune and Brannon 1987). We did not measure many consistent differences in coverage of these plant groups among ungrazed, summer grazed, early grazed, or late grazed sites. Only median dandelion coverage differed between grazed and ungrazed sites. Sites that had been grazed during June since the 1950's tended to have lower canopy coverage of staple herbaceous foods than those in which summer grazing was deferred until after 1 July.

The three most common grasses on plots we measured (timothy, Kentucky bluegrass, and smooth brome) were abundant in most sites. All three species are tolerant of grazing and trampling. The median date for seed production in grasses and sedges on the study area was the first week of July.

Common dandelion and clovers are also low growing plants that tolerate grazing well and were widely distributed in ungrazed, early grazed, and late grazed pastures in the study area. Median dates for production of ripe seeds fell in June. Plants grazed by cattle in June would have time to produce new seed crops. Plants that were in pastures deferred in June would produce seeds and could restore root reserves prior to exposure to cattle.

Grazing patterns vs. herbaceous bear food availability

The five pastures that were monitored for utilization showed that cattle ate or trampled herbaceous bear foods. Almost 50 percent of the biomass of these foods was removed after 6 weeks of grazing by cattle, and by the end of the grazing period, cattle had utilized bear foods in all aspen and willow stands in all pastures.

In 1985 and 1986, cattle were turned into the five pastures in late June or early July when the grassland vegetation was still succulent and the days were cool. Within 2 days, the cattle were evenly distributed over the grasslands. Their rate of movement and consumption when foraging seemed to be dependent on the volume of succulent grasses and how easily they could be procured. When there were no topographical or physical obstructions and forage volume was great, they moved slowly. When the succulent grasses were consumed, became dry, or became unpalatable, cattle either moved faster or shifted to aspen and willow stands to forage.

The cattle first chose open areas within aspen and willow stands where there were ample amounts of succulent vegetation (including herbaceous bear foods) to enable them to fill their rumens with the least amount of effort. Such areas were often used for "shading up" and loafing during the heat of mid-day. Loafing areas were often dominated by grasses, dandelions, and clovers. When these plant species were consumed or trampled, cattle shifted to adjacent areas and fed on the more nutritious bear foods (sharptooth angelica, cow-parsnip, and western sweet-cicely).

Cattle generally consumed the smaller, more tender, lateral stems of these plants before the apical, seed-bearing stems. If the apical stems were mature, they either escaped herbivory altogether or were not eaten until the tender stems were gone, a process which often took 2 to 3 weeks.

Grazing management systems and bear food availability on the East Front

The pattern traditionally followed by ranchers along the East Front when rotating cattle through their pastures affects bear food availability. Many ranchers hold their cattle in willow / hay meadow pastures during winter and early spring. These pastures generally have an abundance of the more desirable bear foods because of favorable moisture regimes due to their locations in drainage bottoms and probably because cattle are moved early enough in spring to allow regrowth of herbaceous plants during the summer.

During May and June, most ranchers release their bulls into pastures occupied by cows for breeding. Many ranchers use small pastures during these 2 months in order to maximize fertilization of cows. This results in a high stocking density in pastures where plants are susceptible to damage from trampling because of relatively high soil moisture and are very attractive to cattle as forage because they are succulent and rapidly growing.

The most palatable umbels evidently cannot tolerate this pressure in June, and pastures used for breeding had low densities of these species. Herbaceous bear foods such as dandelions, clover, and grasses, which have low growth forms that protect them from grazing and either reproduce asexually or produce seed in a short time, can regrow and reproduce if cattle are removed after June. Pastures grazed in June generally had ample amounts of these plants.

After breeding, ranchers move their cows and calves to summer pastures. Summer pastures are usually large and are grazed from July into September. Some ranchers rotate cattle among several pastures during this period. Most summer pastures in the study area contained enough acreage of aspen and willow that the majority of western sweet-cicely and cow-parsnip plants on favorable sites produced seeds before being damaged or consumed by cattle. Sharptooth angelica, the umbel that produced seeds latest in the growing season, seemed to require wetter sites than the other Umbelliferae species. It was locally common at microsites within summer pastures where wet "swampy" areas or dense tangles of willow limbs denied cattle access.

During October, ranchers typically herd their cattle onto hay meadow pastures to fatten cows and calves prior to weaning and selling of the calves. The herbaceous bear foods in these pastures have already shed their seeds and have had time to replenish root reserves for the next year's growth by this time. Of the pastures examined in this study, fall-winter holding pastures generally produced the largest biomasses of nutritious bear foods.

Aune and Brannon (1987) reported the results of food habits analyses of 1,020 grizzly bear scats collected from the East Front during 1979-86. Their results showed that mammals (primarily domestic cattle) were the most frequently found food items in March scats. Mammals and graminoids were the most important bear foods found in April scats. During May, graminoids were most important, followed by forbs, insects, and mammals. Graminoids and forbs were most important during June and July, followed by insects and mammals, respectively.

The changes in diet identified through fecal analysis are closely tied to the manner in which bears use willow and aspen communities along the East Front. In spring, bears routinely visit ranch boneyards in search of dead cattle, and deciduous tree communities along streamcourses provide secure travelways. Dead domestic calves are most abundant in early spring (March and April). This food source is usually consumed by May.

During May and June, some herbaceous bear foods are available virtually everywhere bears travel and in quantities greater than the grizzly bear population within the study area could possibly consume. Aspen and willow stands are rich foraging areas at this time of the year despite elimination or declines in Umbelliferae species due to cattle grazing because of the abundance of grasses, clovers, and dandelions. If one considers that most ranch operations within the study area have annual calving mortality of approximately 5 percent and an annual mortality rate on adult cattle of approximately 1 percent, the biomass of domestic cattle carrion may energetically offset, or surpass, the negative effects of cattle on herbaceous bear foods.

Conclusions

The dominant cattle grazing systems in the East Front study area in 1985-86 were compatible with maintenance of aspen and willow communities. Cattle grazing, particularly in June, does have the potential to decrease abundance of several important herbaceous bear foods in deciduous tree stands along the East Front. These foods include: cow-parsnip, angelica, western sweet-cicely, grasses, clovers, and dandelions. The three umbels (cow-parsnip, angelica, and sweet-cicely) are more likely to be eliminated from stands than the other plant groups. Grasses, clovers, and dandelions are of minor concern since they are tolerant of grazing, widely distributed, and available to bears in excess of their needs. Cattle grazing, as practiced in the study area in 1985-86, provided benefits in the form of carrion that offset much of the damage incurred from loss of palatable plants.

Acknowledgments

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Assessment of Amendments in the Reclamation of an Abandoned Mine in Montana

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Abstract

There are numerous no-responsible-party abandoned mine sites on public lands in western Montana that have been inactive for more than 70 years, yet remain bare of vegetation and drain acidic water to mountain streams. Montana lacks widespread availability of organic materials commonly used in mine reclamation and there is limited information available regarding the efficacy of alternative organic mine reclamation amendments. Replicated field and laboratory studies were undertaken to assess how various surface treatments influence metal mobility and restoration of tailing piles along a second order tributary to the Blackfoot River. Laboratory incubations were carried out by treating tailings with nothing (control), aged log-yard waste, or composted sewage sludge (Eko Kompost, Missoula, MT) with or without lime. After four weeks, tailings were analyzed for pH and exchangeable Pb, Cu, and Fe. Field plots (2 m x 4 m) were treated as above, seeded with native wheatgrass species, and analyzed for pH, exchangeable Pb, Cu, and Fe, microbial biomass, and vegetative cover after eight weeks and 12 months. All liming treatments significantly increased pH and reduced levels of exchangeable metals. Aged log-yard waste alone had little or no effect on pH or levels of exchangeable metals and actually increased levels of exchangeable Pb. Compost applications had only a slight effect on pH, but significantly reduced levels of exchangeable metals and increased levels of microbial biomass. Compost plus lime resulted in the lowest levels of exchangeable metals and greatest vegetative cover. The ability of compost to reduce metal mobility and increase microbial and vegetative activity without a significant change in pH indicate that nutrient availability and reduced metal bioavailability play an important role in site restoration.

Key Words: Log yard waste, composted sewage sludge, metal complexation, restoration.

Introduction

There are currently over eight thousand no-responsible-party abandoned mine sites in western Montana about 30 percent of which reside on federal lands (Montana Bureau of Mines and Geology Abandoned Mine Lands Database, Butte, MT). Many of these sites are abandoned gold, lead (Pb) and copper (Cu) mines that involved the mining and processing of sulfide minerals. The formation of fine textured mine tailings in the processing of the ores creates a high surface area that enhances the oxidation of sulfide minerals to sulfate creating an infertile, highly acidic substrate in which little or no vegetation is established and subsurface drainage and overland flow contribute metal laden acidic drainage to neighboring riparian areas. Most of these mine sites have remained bare of vegetation 70 to 100 years after being abandoned, thus creating a semi-permanent scar on the

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landscape. The lack of a responsible party or federal funds to reclaim these sites requires that an inexpensive and efficient means of site restoration be identified to allow establishment of native vegetation and, thus, reduce metal contamination of surface and ground water and to improve forest aesthetics.

Reclamation of most acid mine sites in Montana is limited to lime applications, to neutralize the acidity of surface soils, and seeding with native grass species (Neuman *et al.* 1993). However, vegetation establishment on limed tailings is greatly limited by poor physical conditions, lack of plant nutrients, and reduced microbial activity, resulting in a gross infertility not readily overcome by the application of synthetic fertilizers (Sopper 1992). For example, revegetation of a heap leach gold mine in Montana was found to be more successful in plots treated with composted sewage sludge or composted yard waste than those plots treated with synthetic N fertilizer (Vodehnal 1993).

The use of composted sewage sludge in the reclamation of abandoned hard rock mine sites has been studied extensively in the Eastern U.S. (Sopper 1992). Sewage sludge provides a source of organic matter, nutrients, and water holding capacity not otherwise available on these abandoned mine sites (Sopper 1992, Rodgers and Anderson 1995). Metal mobility in sewage sludge or composted sewage sludge amended soils or mine tailings may be reduced by surface sorption of metals to the applied organics or by the formation of insoluble organo-metal complexes (Simeoni *et al.* 1984, Pritchel *et al.* 1989, Leita and De Nobili 1991, Cavallaro *et al.* 1993). Metals that are complexed by humic acids (>10,000 dalton polyphenolic compounds) tend to be insoluble, whereas metals complexed by fulvic acids (several hundred dalton polyphenolic compounds) normally remain soluble (Stevenson, 1994). The humic acid content of sewage sludge is increased during the composting process thereby improving the physical and biochemical properties of sludge as soil amendment and increasing the concentration of metal complexation sites within the amendment (Simeoni *et al.* 1984, Leita and De Nobili 1991).

The population density of the eastern United States results in the production of large quantities of sewage sludge; however, the industrial density of these same regions results in sewage sludge that has high concentrations of heavy metals. The metal concentrations found in eastern sewage sludge often precludes its application to cropland, but is, instead, used in mine reclamation (Sopper 1992). The low population density in Montana greatly reduces the widespread availability of organic materials commonly used in mine reclamation. Aged log-yard waste (LYW) is available across western Montana and has been identified as a possible amendment for abandoned mine restoration (Campbell and Tripepi 1992).

It is not clear how LYW might influence metal mobility compared with lime or compost. The humification process of composting sewage sludge with wood waste should result in a higher ratio of humic acid to fulvic acid than aged LYW (Leita and De Nobili 1991). Complexation of metals by humic acids greatly reduces metal solubility compared to fulvic acids (Sposito *et al.* 1982, Stevenson 1994).

The purpose of the work reported was to assess the effect of surface applied composted sewage sludge or aged LYW with and without lime application on: (1) concentrations of exchangeable metals in acid mine tailings; (2) levels of microbial biomass and revegetation success; and (3) restoration of a small no-responsible-party abandoned mine site in western Montana.

Table 1. *Physical and chemical characteristics of mine tailings (Sandbar Creek) and organic amendments.*

		Characteristics						
					Organic	Total Digestible		
Material	pH[1]	Sand	Silt	Clay	C[2]	Fe[3]	Cu[3]	Pb[3]
		g/kg				mg/kg		
Sandbar Creek	2.7	480	200	320	44	4,580	540	240
Eko Kompost	6.3				3,400	345	257	9
LYW	7.5				3,500	95	14	1

[1] pH determined in a 2:1 solution (0.01 M $CaCl_2$)
[2] Total organic C determined by Walkley Black method (Nelson and Sommers, 1982).
[3] Total digestible (aqua regia digest) Fe, Cu, and Pb, analysis on inductive coupled plasma spectrophotometer.

Study Area

Laboratory and field experiments were carried out on mine tailings from a small abandoned mine along Sandbar Creek in the Helena National Forest near Lincoln, Montana. The chemical and physical characteristics associated with the mine tailings and organic materials are given in Table 1. Analysis of total digestible metals (aqua-regia digest and analyses on ICP) led us to focus our experiments on levels of exchangeable Pb, Fe, and Cu.

Materials And Methods

Laboratory studies were conducted on dried and sieved (2 mm) mine tailings collected from Sandbar Creek. Tailing samples of 100 g were amended with either nothing, 10 g or 20 g of composted sewage sludge (Eko Kompost, Missoula, MT), or 10 g of aged LYW (Lincoln Pole Yard, Lincoln, MT), with or without the addition of lime as 1.5 g of $CaCO_3$ and 1 g CaO to bring the tailings pH to 6.5 (Adams and Evans 1962). The treated tailings were brought to 60 percent water holding capacity, mixed thoroughly, and placed in 250 ml French square bottles and allowed to incubate in a constant temperature chamber for 4 weeks. Water content was measured and adjusted on a weekly basis. Exchangeable metals were extracted by adding 100 ml of 2 M KCl to each bottle. The suspensions were shaken for 60 minutes, filtered through Whatman #2 filter papers, and then analyzed for Pb, Fe, and Cu by atomic adsorption spectrophotometer (AAS) (Baker and Amacher 1982, Burau 1982, Olson and Roscoe 1982).

Field plots were established by preparing 20-2 m by 4 m plots in a randomized complete block design on two sets of tailings piles at Sandbar Creek. Plots were amended with either nothing (control), 30 Mg lime as CaO/ha (to bring tailings pH to 6.5, (Adams and Evans 1962), 24.4 Mg LYW/ha, 24.4 Mg composted sewage sludge/ha with and without lime. Lime was incorporated to a depth of 15 cm and compost and LYW were incorporated to a depth of 7.5 cm. Plots were seeded with 20 kg/ha of slender wheatgrass and thick spike wheatgrass, raked in to a depth of 3 cm, and watered weekly for 3 weeks. Field plots were sampled to a depth of 7.5 cm 8 weeks and 12 months after treatment and analyzed for microbial biomass (DeLuca and Keeney 1993), pH, and exchangeable metals (Pb, Cu, and Fe) as described above. Plots were observed for percent grass surface cover 12 weeks and 12 months after treatment. Numbers of seed heads per plot and numbers of native pine seedlings per plot were counted 12 months following treatment. Data were analyzed by analysis of variance using PC-SAS (SAS Institute). Mean separations were determined by lsd ($P < 0.05$).

Results And Discussion

Concentrations of exchangeable metals in mine tailings from Sandbar Creek were significantly reduced by both compost and lime treatments (Table 2). Copper, Fe, and Pb were the only metals present in significant quantities in the Sandbar Creek mine tailings, based on an aqua-regia digest and analyses on ICP. Lime applications increased tailings pH to 7.0 and reduced exchangeable Pb, Fe, and Cu by 84 - 100 percent. This decrease in exchangeable metals with an increase in pH primarily reflects the precipitation of Pb, Cu, and Fe into insoluble oxide forms (Lindsay 1979). The 10 percent compost application rate resulted in a significant decrease in exchangeable metals, but no change in pH. The 20 percent compost application rate increased pH to 3.4, reduced the exchangeable metals concentrations by 60 to 95 percent, and resulted in exchangeable Cu and Fe concentrations that were not significantly different from lime amendments.

Log yard waste resulted in only a slight decline in exchangeable Cu and Fe and actually increased levels of exchangeable Pb compared to the control (Table 2). DeLuca and Lynch (1996) reported that levels of water soluble Fe were increased by LYW applications and that water soluble Cu levels were detectable only in the control and in LYW treated tailings from Sandbar Creek. The increase in exchangeable Pb and water soluble Fe may have been a result of the greater concentration of low molecular weight of organic complexes associated with the non-humified LYW (DeLuca and Lynch 1996) resulting in colloid assisted mobility (Stevenson 1994). There was no antagonistic effect of compost or log yard waste on lime amendments. These results underscore the ability of compost to complex metals and reduce their bioavailability in acidic mine tailings with or without lime additions (Sopper, 1992), but bring into question the utility of LYW as a reclamation amendment.

Results obtained in field studies were similar to those found in the laboratory (Table 3, 4). Lime treatments

Table 2. *Tailings pH and concentration of exchangeable Pb, Fe, and Cu in Sandbar Creek mine tailings treated with compost or log-yard waste (LYW) with or without lime, lime alone or no treatment and incubated in the laboratory at 25°C for 4 weeks.*

Treatment	Exchangeable[1]			
	Pb	Fe	Cu	pH
	mg/kg			
Control	14.6	256	14.4	2.9
Lime	4.6	12	0.0	7.1
LYW	18.2	186	10.0	3.0
10% Compost	10.4	42	3.2	3.0
20% Compost	8.4	12	0.4	3.4
LYW + Lime	3.8	12	0.0	6.9
10% Comp. + Lime	4.2	12	0.0	7.0
20% Comp. + Lime	2.4	10	0.0	6.9
lsd ($P < 0.05$)	1.4	28	0.5	0.2

[1] Exchangeable metals measured by extraction of tailings with 2 M KCl and analysis on atomic absorption spectrophotometer

greatly reduced the levels of exchangeable metals in the surface 7.5 cm of mine tailings. Compost applications alone significantly increased tailings pH and reduced levels of exchangeable Pb and Fe over the control during the first growing season and 12 months after treatment. Unlike lime amendments, compost applications reduce levels of exchangeable metals primarily by surface sorption and by the formation of organo-metal complexes (Stevenson 1994). Although these organic complexes may degrade over time, we observed no significant change in levels of extractable metals on compost treated plots one year following treatment. Log-yard waste had no significant effect on tailings pH nor on levels of exchangeable Pb, Fe, or Cu (Table 3, 4). The high level of exchangeable Fe found in the control

Table 3. *Tailings pH and concentration of exchangeable Pb, Fe, and Cu in Sandbar Creek mine tailings 8 weeks following treatment of tailings with compost, log-yard waste (LYW), compost plus lime, lime alone, or no treatment.*

Treatment	Exchangeable[1] Pb	Fe	Cu	pH
	-----------	mg/kg	-----------	
Control	294	585	10.7	2.6
Lime	4	8	0.7	9.2
LYW	234	416	8.9	2.8
Compost	55	31	2.8	3.5
Compost + Lime	3	10	0.4	8.6
lsd ($P < 0.05$)	221	428	10.8	0.9

[1] Exchangeable metals measured by extraction of tailings with 2 M KCl and analysis on atomic absorption spectrophotometer.

Table 4. *Tailings pH and concentration of exchangeable Pb, Fe, and Cu in Sandbar Creek mine tailings 12 months following treatment of tailings with compost, log-yard waste (LYW), compost plus lime, lime alone, or no treatment.*

Treatment	Exchangeable[1] Pb	Fe	Cu	pH
	-----------	mg/kg	-----------	
Control	328	291	10.3	2.6
Lime	4	17	0.6	8.3
LYW	298	247	9.4	2.7
Compost	80	47	0.6	3.1
Compost + Lime	5	17	0.6	7.8
lsd ($P < 0.05$)	107	216	10.8	1.0

[1] Exchangeable metals measured by extraction of tailings with 2 M KCl and analysis on atomic absorption spectrophotometer.

and LYW plots eight weeks following treatment was a likely result of the high variability associated with the placement of plots on two separate tailings piles or, perhaps, a function of the oxidation of Fe exposed to air over an eight week period following the mixing of tailings to a 15 cm depth without application of treatments that reduce metal mobility.

Microbial biomass C as estimated by fumigation-extraction is a good index of the active fraction of C in soils (Tate 1995). Microbial biomass was greatest in compost treated plots and was higher in compost alone plots than in compost plus lime plots (Fig. 1). The initial levels of microbial biomass in the surface 7.5 cm of compost treated mine tailings were similar to that found in the surface 7.5 cm of native riparian soil (579 mg biomass C/kg soil) at Sandbar Creek. However, levels of microbial biomass declined from over 600 mg/kg eight weeks following treatment to about 350 mg/kg 12 months following treatment. Microbial biomass was found to be significantly greater than the control only in compost treated plots 12 months following treatment. Microbial biomass in tailings treated with lime was significantly greater than the control 8 weeks following treatment, but this difference was not observed 10 months later. Tailings treated with LYW showed no significant change in microbial biomass.

Grass was unable to germinate or grow on the control or LYW treated plots (Fig. 2), which was likely a result of a lack of available nutrients. The application of LYW as an organic amendment to tailings piles did not positively influence vegetation establishment or microbial biomass because of the high C:N ratio (560:1) and high metal bioavailability on these plots. Grass establishment was observed on lime and compost treatments and was greatest on compost plus lime plots. It should be noted however, that the grass establishment numbers are based on percent ground cover and not on biomass production. The grass growing on the lime alone plots was highly chlorotic and had burned tips, whereas the grass on the compost treated plots was green, thick, and healthy. Compost treatments supply N and P that were likely limited on the lime treated plots. Grass on compost plus lime treated plots had an average of nine seed heads/plot compared to less than one per plot for all other treatment. The

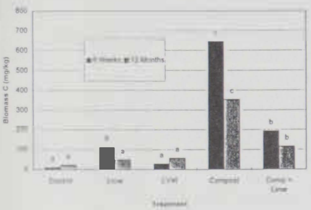

Figure 1. *Microbial biomass in surface 7.5 cm of tailings 8 weeks and 12 months after treatment with lime, log-yard-waste (LYW), compost, or compost plus lime. For a given date, bars with the same letter are not significantly different (P ≥ 0.05).*

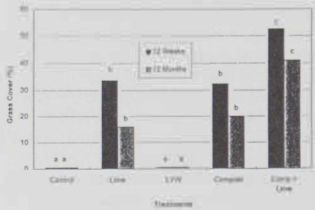

Figure 2. *Percent vegetative cover on plots 12 weeks and 12 months after treatment with lime, log-yard-waste (LYW), compost, or compost plus lime (for a given date, bars with the same letter are not significantly different (P ≥ 0.05).*

compost plus lime plots were found to have eight native pine seedlings/plot one year after treatment compared to three for lime treated plots and two/plot on compost alone and control plots.

The observed decline in levels of microbial biomass in compost treated tailings was likely a result of the decomposition of metabolic organic matter associated with the compost. This suggests that annual applications of composted sewage sludge might have to be made for long term effective reclamation of acidic mine tailings. Alternatively, the annual degradation of plant shoot and root biomass on compost treated plots may ultimately offset the loss of metabolic organic matter from the compost, allowing the system to eventually reach steady state.

Plots receiving compost alone maintained the highest levels of microbial biomass and allowed for grass establishment with only a slight increase in tailings pH through the first year following treatment. This indicates that nutrient availability and reduced metal bioavailability, afforded by compost applications, may play a more important role in site restoration than correction of tailings pH.

Conclusions

Both lime and compost applications alone or in combination were effective at reducing levels of exchangeable metal concentrations in mine tailings 1, 2, and 12 months following treatment. Compost alone had no significant effect on pH, but greatly reduced levels of exchangeable metals as a result of metal sorption and complexation. Log-yard-waste applications had little or no effect on levels of exchangeable metals and actually increased Fe solubility in laboratory studies. Amendment of tailings with compost increased microbial biomass and allowed for the initiation of vegetative growth on the tailings piles at Sandbar Creek for the first time since their deposition. Lime applications initially increased microbial biomass, but these levels were not different from the control 12 months following treatment.

The establishment of grass should reduce overland flow and decrease leaching with increased evapo-transpiration associated with plant growth. Increased plant growth on these plots will begin to increase levels of soil organic matter resulting in continued microbial activity. The aged LYW used in this study does not appear to be an effective medium for mine reclamation without the addition of a N source. The C:N ratio of the LYW is about 560:1 resulting in rapid immobilization of available N and limited microbial activity. The material also has little effect on metal mobility, and may actually increase metal solubility in some cases. It is recommended that this material only be used in the presence of an added N source or following composting to reduce the C:N ratio and increase the humic acid content thereby increasing its utility in the reclamation of acid mine tailings. The effect of compost applications on reducing levels of exchangeable metals, establishment of vegetation, and enhancement of microbial biomass with little or no effect on tailings pH indicates that nutrient availability and reduced metal bioavailability may play a more important role in site restoration than correction of tailings pH via liming. However, the combination of lime and composted sewage sludge clearly provided the most effective reclamation amendment in our studies.

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Randall R. Skelton

How Children Score on Discriminate Functions Designed for Adults

Abstract

Existing discriminant functions for sex, as used in forensic anthropology, are designed to be used with adults. The question of how well they work with children has not been adequately explored. I constructed a discriminant function for sex using 7,428 adults from the Boas Anthropometric Data Set and used the function to estimate sex for 6,102 children from this data set. I examined the accuracy of sexing for individuals of all ages. The accuracy was about 50 percent for people 12 and under, about 90 percent for people 19 and older, and increased in a nearly linear fashion between ages 12 and 19. The function scores small people as female.

Key words: discriminant functions, forensic anthropology, sexing.

Introduction

Forensic anthropology is the application of the methods and expertise of physical anthropology to the legal process. In one common situation, the anthropologist takes custody of skeletal material provided by a law enforcement agency and attempts to determine the age, sex, race, height, and medical history of any represented human beings. The anthropologist's findings may then be used to scan lists of missing persons in an attempt to determine the identity of the deceased (Haviland, 1994). One of the important identifying items in a missing person's description is their sex and many forensic anthropologists have discussed methods of estimating sex from the skeleton (Dutra 1944, Brues 1958, Ubelaker 1978, Stewart 1979, Snow 1982, Krogman and Iscan 1986, Rogers 1986, Bass 1987, Bennett 1987, Steele and Bramblett 1988, Iscan and Kennedy 1989, Rogers 1989, Killam 1990, White and Folkens 1991).

There are two useful approaches to estimating sex from skeletal material. In the first approach the anthropologist visually inspects the skeleton, looking for characters that are more commonly associated with one sex than the other (Derry 1909, Derry 1912, Pearson 1914, Parsons 1920, Derry 1923, Thoms and Greulich 1940, Washburn 1948, Thieme and Schull 1957, Phenice 1969, Kelley 1978, Weaver 1980, Lovell 1989, Anderson 1990, Budinoff and Tague 1990, Hunt 1990, Maclaughlin and Bruce 1990, Sutherland and Suchey 1991, Schutkowski 1993). These characters are primarily features of the pelvis and skull, although other elements of the skeleton can occasionally be useful. In the second approach, the anthropologist measures parts of the skeleton and plugs these measurements into a computer-generated formula, called a discriminant function. The discriminant function yields a score, which can be interpreted as indicating that the person is of one sex or the other (Hanihara 1958, Hanihara 1959, Giles and Elliot 1963, Giles 1964, Steel 1966, Ditch and Rose 1972, Day and Petcher-Wilmott 1975, Steele 1976, Henke 1977, Flander 1978, Dibennardo and Taylor 1983, Owlsey and Webb 1983, Dittrick and Suchey 1986, De Vito and Saunders 1990, Holman and Bennett 1991). Both of these approaches are useful, and

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good forensic analyses utilize both of them.

It is generally recognized that sex determination is unreliable for young children because secondary sexual characteristics are not manifested until puberty (Bass 1987). Visual methods are at least occasionally reliable for individuals who are postpubertal, but who have not achieved full skeletal maturity (Steele and Bramblett 1988, Schutkowski 1993). However, the question of whether discriminant functions can be used to estimate sex in adolescents remains unanswered. Existing discriminant functions are designed for use with adults. The question of how children and adolescents score on these functions has not been adequately explored.

The study reported herein is part of a continuing effort by various members of the forensic anthropology team at The University of Montana - Missoula to explore and identify the limitations of the discriminant functions approach to estimating sex and race (Stagg 1993, Skelton 1994, Olson 1995). In this study I will examine how children score on discriminant functions for sex that are designed for use with adults.

Materials and Methods

I worked with the Boas Anthropometric Data Set, which was kindly provided by R.L. Jantz and S. Ousley of the University of Tennessee, Knoxville (Jantz *et al.* 1992) This data set includes six cranial and six postcranial measurements on over 15,000 living Native Americans of various tribes. These data were collected about 100 years ago by colleagues of Franz Boas, a prominent historical figure in American anthropology (Hays 1964). Although the Boas data set consists of measurements of living people and, therefore, cannot be applied directly to investigations of the skeleton, these measurements should behave similarly to skeletal measurements.

The Boas data set includes data for individuals of all ages and both sexes. I chose to work with individuals who had no missing values for any of the 12 measurements. This gave me 13,530 cases with complete data. Table 1 provides a breakdown of the sample by age and sex. For presentation and plotting purposes, people age 30 through 59 are grouped by 10-year age category. Similarly, all people 60 and over are grouped into a single category.

A discriminant function for sex was constructed for the individuals age 20 and older, using the SPSS-X Discriminant procedure on the U.M. campus mainframe. This function was then used to classify all 13,530 individuals in the data set. Mean sexing accuracy by age was calculated and plotted. Overall sexing accuracy was obtained by averaging the accuracies for the males and the females.

Three methods of correcting for the effect of size were applied to the data. First a principal components analysis was performed using the SPSS-X Factor procedure (Andrews and Williams 1973, Morrison 1976, Karson 1982, Berenson *et al.* 1983, Darroch and Mosimann 1985). Second, a form of size scaling was attempted, wherein the values for each of the variables are summed to yield an overall size variable. Each value was then divided by the overall size variable (Albrecht *et al.* 1993). This method is widely acknowledged to be an ineffective way to adjust for the effect of size (Atchley *et al.* 1976, Corruccini 1985, Gelvin and Albrecht 1985, Reist 1985, Packard and Boardman 1987, Gelvin *et al.* 1991, Albrecht *et al.* 1993). Third, the data were divided into three age groups: 1 to 12, 13 to 19, and 20 or older. Each variable was regressed on age, using the SPSS-X Regression procedure, separately for each of the age groups. The residuals for each variable, after the effect of age was accounted for by this procedure, were retained and a discriminant analysis was performed

Table 1. *Sample sizes and classification results by age and sex.*

AGE	Number of Females	Females Correctly Classified (%)	Number of Males	Males Correctly Classified (%)	Total Number of Individuals	Total Correctly Classified (%)
1	6	6 (100 %)	10	0 (0 %)	16	6 (38 %)
2	4	4 (100 %)	19	0 (0 %)	23	4 (17 %)
3	26	26 (100 %)	31	0 (0 %)	57	26 (46 %)
4	49	49 (100 %)	42	1 (2 %)	91	50 (55 %)
5	61	61 (100 %)	79	0 (0 %)	140	61 (44 %)
6	114	114 (100 %)	120	0 (0 %)	234	114 (49 %)
7	143	143 (100 %)	143	0 (0 %)	286	143 (50 %)
8	193	193 (100 %)	213	0 (0 %)	406	193 (48 %)
9	185	185 (100 %)	234	0 (0 %)	419	185 (44 %)
10	199	199 (100 %)	241	2 (1 %)	440	201 (46 %)
11	213	213 (100 %)	242	0 (0 %)	455	213 (47 %)
12	230	230 (100 %)	319	1 (0 %)	549	231 (42 %)
13	206	206 (100 %)	262	7 (3 %)	468	213 (46 %)
14	204	204 (100 %)	274	14 (5 %)	478	217 (45 %)
15	193	190 (98 %)	269	59 (22 %)	462	249 (54 %)
16	198	189 (95 %)	232	88 (38 %)	430	277 (64 %)
17	161	156 (97 %)	208	140 (67 %)	369	296 (80 %)
18	202	189 (94 %)	223	162 (73 %)	425	351 (83 %)
19	130	119 (92 %)	224	190 (85 %)	354	309 (87 %)
20	150	138 (92 %)	266	233 (88 %)	416	371 (89 %)
21	64	57 (89 %)	207	185 (89 %)	271	242 (89 %)
22	108	101 (94 %)	220	194 (88 %)	328	295 (90 %)
23	76	68 (89 %)	153	142 (93 %)	229	210 (92 %)
24	47	44 (94 %)	142	131 (92 %)	189	175 (93 %)
25	100	94 (94 %)	244	211 (86 %)	344	305 (89 %)
26	43	39 (91 %)	139	122 (88 %)	182	161 (88 %)
27	57	52 (91 %)	138	130 (94 %)	195	182 (93 %)
28	84	78 (93 %)	176	158 (90 %)	260	236 (91 %)

using them (Albrecht *et al.* 1993). Finally, the sexing accuracies by age of the size-scaling and the residuals procedures were averaged and plotted as described above.

Results And Discussion

The results obtained from the original discriminant analysis procedure are shown in Figure 1. The accuracy of sexing females age 13 and younger was effectively 100 percent, the accuracy of sexing females age 19 and older was around 90 percent, and the accuracy of sexing females age 14 through 18 declined from about 100 percent to about 90 percent in a fairly linear fashion with increasing age. The accuracy of sexing males age 12 and younger was effectively 0 percent, the accuracy of sexing males age 19 and older was around 90 percent, and the accuracy of sexing males age 13 through 18 increased from about 0 percent to about 90 percent in a fairly linear fashion with increasing age. The combined accuracy of sexing people 12 and younger was around 50 percent, the combined accuracy of sexing people age 19 and older was around 90 percent, and

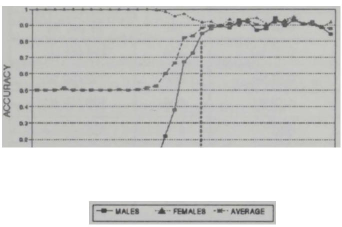

Figure 1. *Sexing accuracy: unmodified data*

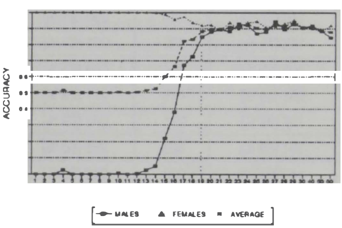

Figure 2. *Sexing accuracy: size-scaled data*

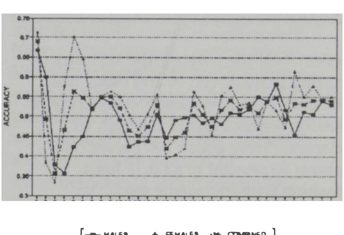

Figure 3. *Sexing accuracy: residuals*

the accuracy of sexing people age 13 through 18 increased from around 50 percent to around 90 percent in a fairly linear fashion with increasing age.

These results imply that size is the primary factor reflected in the discriminant function, and that small people are classified as female.

The above results also imply that discriminant functions for sex are highly accurate only for people age 19 and older. People age 15 to 18 can be sexed with moderate accuracy (around 60 percent to 80 percent), but the accuracy of sexing people younger than 15 by this method is not significantly different from random chance (or more accurately, no better than classifying all individuals as female).

None of the methods of adjusting for the effect of size was useful. The principal components analysis yielded only one principal component, upon which all variables loaded moderately high, and which can be interpreted as size.

The results obtained using data scaled by the overall size variable are shown in Figure 2, and are identical to those obtained using unmodified values.

The results obtained using the residuals left after the effect of age was removed are shown in Figure 3. The sexing accuracy is effectively 50 percent across all age groups. The variability in accuracy by age is quite variable for people younger than about 8, probably due to the relatively smaller sample sizes for these younger ages and to nonlinear growth early in life.

Conclusions

The primary conclusion is that sexing by discriminant functions is highly reliable only for individuals 19 or more years old. Therefore, they should be applied only to individuals showing evidence of skeletal maturity, such as erupted 3rd molars, closure of the basilar suture, or closure of all epiphyses of the long bones.

The secondary conclusion is that, at least in this study, discriminant functions detect only sexual dimorphism in size, with small people being classified as female. There does not seem at this time to be a way to correct for size differences in such a way that children can be sexed accurately using discriminant functions designed for adults.

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