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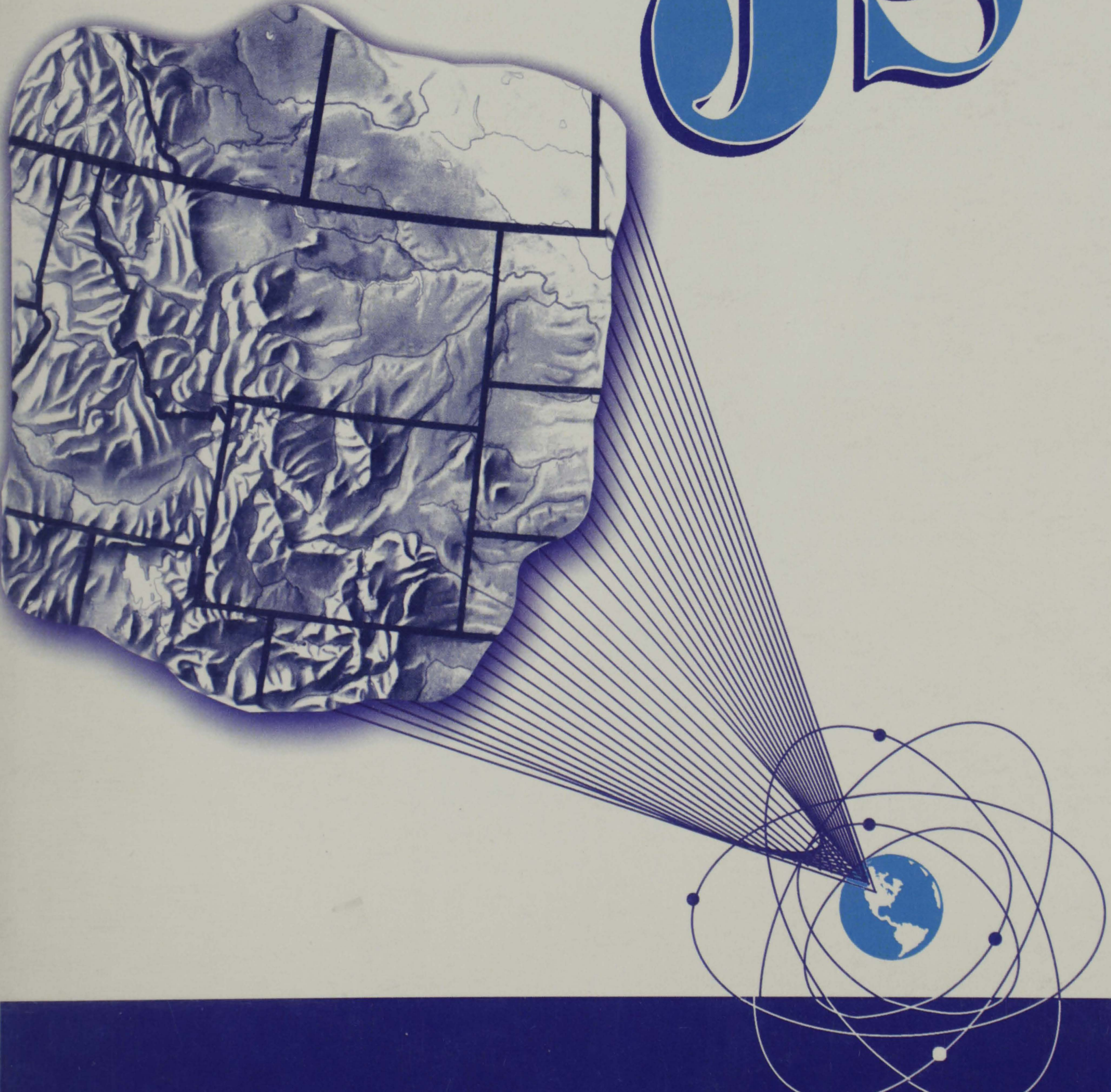

INTERMOUNTAIN JOURNAL OF SCIENCES

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

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

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LITERATURE CITED

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

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LATE WINTER DISTRIBUTION OF STONECATS IN THE MISSOURI AND LOWER SUN RIVERS, UPSTREAM OF GREAT FALLS, MONTANA

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ABSTRACT

Although stonecats (*Noturus flavus*) are native to the Missouri and Yellowstone river drainages in Montana, little is known about their distribution or population characteristics. Stonecats were first collected in the Missouri River near Craig, Montana in 1892. However, during extensive annual electrofishing surveys over the past 25 years in the same area, no stonecats had been collected. Hoop nets and cod traps were fished in the Missouri River during March 2005 and 2006, and slat traps were fished during March 2006 to target smaller fish. Stonecats were only collected in the most downstream 19 km of the Missouri River study reach No stonecats were collected in cod traps. In 2005, mean hoop net catch rates were 2.8 stonecats/2-night period in the most downstream 19-km reach of the Missouri River, and no stonecats were collected in the 2006 Missouri River hoop nets. Slat trap catch rates in the 19-km reach of the Missouri River were 0.2 stonecats/2-night period in 2006. In 2006, hoop nets and slat traps were fished in the Sun River. Mean hoop net and slat trap catch rates in the Sun River were 4.8 and 6.5 stonecats/2-night period, respectively. Our results indicate that stonecats may be limited to the lower 1.9 km of the Missouri River (> 120-km downstream from the 1892 collection). We hypothesize that stonecat distribution has changed due to the cumulative effect of upstream reservoirs (Canyon Ferry, Hauser, and Holter) on the downstream water temperature regimens.

Key words: hoop net, *Noturus flavus*, stonecat, slat trap, upper Missouri River

INTRODUCTION

The native distribution of stonecats (*Noturus flavus*)—a small yellowish-brown catfish—extends in North America from southern Canada to the Prairie Region of the Midwestern U.S., and from the Rocky Mountains to the Hudson, Allegheny, and Mohawk basins in New York (Scott and Crossman 1973, Pflieger 1997). The Upper Missouri River in Montana represents the western edge of the stonecats distribution. In 1892 stonecats were documented in the Missouri River near Craig, Montana (Brown 1971). General distribution data exist for stonecats throughout the Missouri River Basin, but these records were typically the result of incidental samples (Montana Fish, Wildlife and Parks unpublished data). Therefore, little was known about specific populations, i.e., density, life history, size structure, of stonecats in Montana. In 2005 while conducting a project to determine burbot (*Lota lota*) distribution in a 152-km reach of the Missouri River (Horton and Strainer 2008), we collected adult stonecats in the most downstream reach of the study area. Therefore, objectives for this study were to test the effectiveness of hoop nets, slat traps, and cod traps for capturing stonecats and to determine stonecat distribution and population characteristic in a 152-km reach of the Missouri River upstream of Great Falls, Montana, and the lowermost 10.2-km of the Sun River in Northcentral Montana.

STUDY AREA

The study area was located in the Upper Missouri River Basin in Northcentral Montana (Fig. 1). Sampling was conducted

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on a 152-km reach of the **Missouri River** beginning at Holter Dam near Helena, Montana and proceeding downstream to Black Eagle Dam in Great Falls, Montana. **Sampling** was also conducted on the lowermost 10.5 km of the Sun River—a major tributary to the Upper Missouri River that enters from the west near Great Falls, Montana. Three reservoirs (Canyon Ferry, Hauser and Holter) impound the Missouri River immediately upstream from the study area. A variety of habitat changes occur along the 152-km reach. Influences from upstream dams on discharge and water-temperature diminish progressively downstream. Geological features laterally control much of the upper river channel, where stream gradient is highest. The river becomes highly sinuous downstream of the Dearborn River (~ 45km downstream of Holter Dam; Fig. 1) with smaller substrate, increased turbidity, and increased water depth.

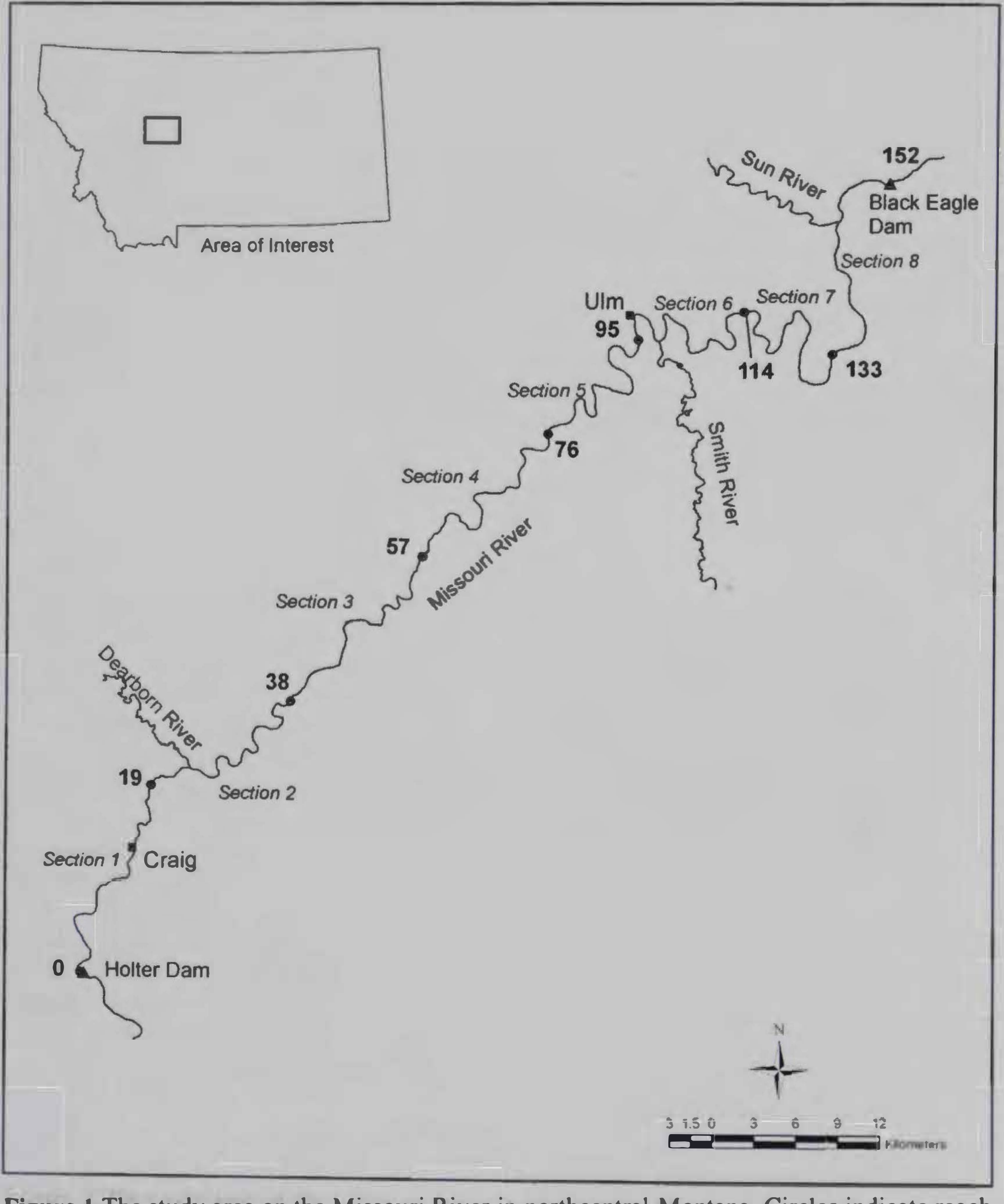

Figure 1.The study area on the Missouri River in northcentral Montana. Circles indicate reach boundaries with corresponding river kilometers downstream from Holter Dam.

MEHODS

Hoop nets, cod traps, and slat traps were fished throughout the study area; we baited all gear types with previously frozen longnose suckers (*Catostomus catostomus*) and white suckers (*C. commersoni*), which are common non-game species in the study area. Hoop nets measured 3.05-m long, maximum hoop diameter was 61 cm, and mesh size was 2.5 cm (bar measure; Paragamian 2000). Cod trap frames were constructed from 1.3-cm rebar (Spence 2000). The bottom hoop diameter was 1.0 m, the top hoop diameter was 69 cm, and the trap height was 64-cm tall. Nylon mesh (1.3-cm bar measure) covered the structure, and a 25-cm wide oval-shaped throat entered the trap from the side. Wooden slat traps measured 61-cm long, 30-cm wide, and 30-cm tall. The slat trap opening was constructed from a sheet of plastic mesh (6-mm bar measure) that was formed into a funnel. The throat of the funnel measured 5.7 cm. The maximum distance between wooden slats was 1.6 cm.

In order to systematically and logistically sample the 152-km long study area on the Missouri River, we divided the study area into eight 19-km reaches. All sampling occurred during March, and the reach sampling order was randomly determined. Cod traps and hoop nets were fished in 2005 and 2006, and slat traps were fished in 2006 to target smaller fish. We set hoop nets on both sides of the river at ~ 2-km intervals throughout the Missouri River study area. Each hoop net was fished for one 2-night period. One cod trap was fished for three 2-night periods in each reach on the Missouri River. Cod traps were fished in backwater and eddy areas. Two slat traps were fished for three 2-night periods in each reach. During each 2-night period slat traps were fished in the same area on opposite sides of the river. Spacing between slat trap sets averaged ~ 5.9 km. The 10.5-km reach of the Sun River was only sampled during March 2006. Net spacing was similar to the Missouri River, but due to the narrower river width only one net or trap was fished at each location. We recorded length and weight on all fish. We used a Kolmogorov-Smirnov two-sample test to detect differences in length distributions between stonecats captured in hoop nets and slat traps.

RESULTS

The 2005 mean water temperature in the Missouri River during the study was 3.1 °C (SE 0.04), compared to 2 °C (SE 0.08) in 2006. For comparison, the mean water temperature in the lower Sun River was 5.9 °C, during the sampling period in 2006. A total of 93 stonecats were captured; 79 were collected in hoop nets, 14 in slat traps, and no stonecats were collected in cod traps. Hoop nets were fished for nearly300 2-night periods, and cod and slat trap effort. individually, was approximately 50 2 night periods. In the Missouri River stonecat were collected only in the most downstream 19 km of the study area (herein referred to the Great Falls reach). In addition, stone were only collected in Missouri River hoop net sets during 2005. Hoop net catch rate ranged from 0 to 33 per 2-night period (Table 1). In 2005, the mean hoop net catch rate was 2.8 stonecats per 2-night period, in the Great Falls reach. In the entire Missouri River study area the mean slat trap catch rate was 0.17 (SE = 0.17) stonecats per 2-night period, because only one stonecat was captured in one set. In the Sun River, the mean hoop net catch rate was 4.8 (SE –2.9; catch ranged from 0 to 19) stonecats per 2-night period. The mean slat trap catch rate was 6.5 (SE = 2.5; catch ranged from 4 to 9) stonecats per 2-night period. Mean length of all stonecats collected in the Missouri River was 220 mm (SE = 2.4; length ranged from 180 to 251 mm) compared to 227 mm (3.5 = SE; length ranged from 178 to 290 mm) in the Sun River. The length distributions of stonecats captured with hoop nets and slat traps were not significantly different (KSa – 0.98; *P* > KSa = 0.2896; Fig. 2).

DISCUSSION

In 2005 we collected 50 stonecats in the Missouri River; however, only one stonecat was collected during the 2006 season. Differences in water temperature between

Table 1. Mean, standard error (SE), minimum, and maximum catch rates (number/2-night period), by site [Missouri River (MOR) and Sun River (SUNR)], gear type and year.

Catch Rate Site	Gear	Year	Mean	SE	Minimum	Maximum
MOR	Hoop net	2005	0.4	0.2	0.0	33.0
		2006	0.0	0.0	0.0	0.0
	Slat trap	2006	0.2	2.9	0.0	1.0
SUNR	Hoop net	2006	4.8	2.9	0.0	19.0
	Slat trap	2006	6.5	2.5	4.0	9.0

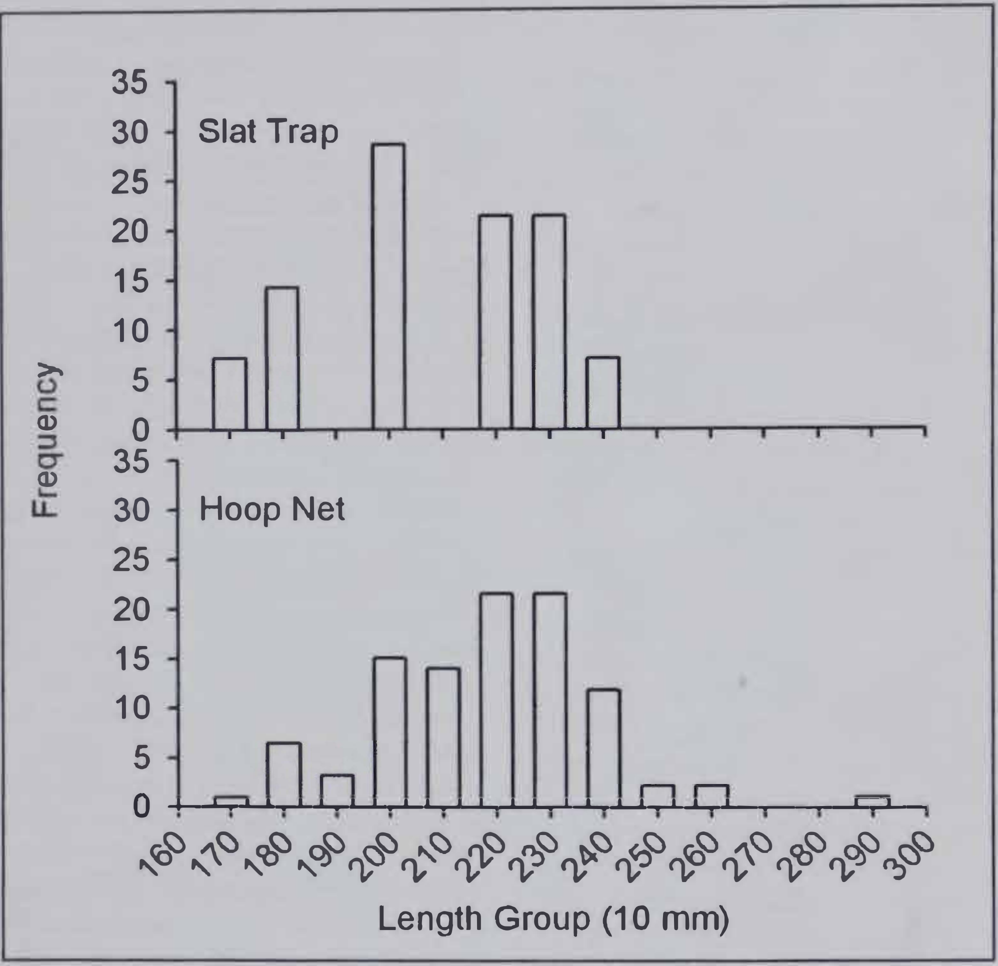

Figure 2. Length frequency distribution of stonecats captured in hoop nets and slat traps, all reaches and years combined.

years may have reduced the catch in 2006. In addition the 2006 mean water temperature in the Sun River was greater than mean water temperatures in the Missouri River in 2006, and may have resulted in a higher stonecat capture rate. Coker et al. (2001) classify stonecats thermal preference as "warm" since they prefer temperatures > 25 °C. In fact, spawning occurs when water temperatures exceed 27 °C in some areas (Scott and Crossman 1973, Walsh and Burr 1985). Catch rates in our study may have been higher if sampling was conducted in a warmer season when stonecats are more active.

We are unaware of literature that describes sampling stonecat populations in large-river systems. In our study, baited hoop nets and slat traps proved effective for sampling stonecats in the Missouri and Sun rivers. In addition, stonecats collected in this study were large individuals; generally longer than lengths reported in the literature. For example, Brown (1971) reported sizes from 76 to 177 mm, with some specimens reaching 305-mm TL. Other published length ranges rarely reached the length of our smallest stonecats (Trautman 1981, Etnier and Starnes 1993, Jenkins and Burkhead 1993). Sampling stonecats in other parts of their range—where growth rates and population size structure may be different —may require gear with smaller mesh (or slat gaps) than those we used. It is unknown why smaller stonecats were not captured during our study. Possible explanations suggest that hoop net mesh size or slat trap gaps were too large, or no small stonecats were present. Length distributions of stonecats captured by hoop nets and slat traps in this study were not significantly different despite differences in mesh size and slat gap openings between the gears.

Stonecats may disappear from streams that are impounded (Scott and Crossman 1973). Pre-impoundment records documented stonecats in the Missouri River near Craig, Montana, located in the upstream portion (~9 km downstream from Holter Dam) of the 152-km long study area (Brown 1971); however, during this study stonecats were only caught in the most downstream 19 km of the Missouri River study area. More than 110 km separates these two areas. Moreover, Montana Fish, Wildlife and Parks has conducted biannual (Spring and Fall) electrofishing surveys since the early 1980s in the areas near Craig and Cascade (~ 9 km and 43 km downstream from Holter Dam, respectively), Montana, but no stonecats have been documented during these efforts (MFWP unpublished data). In comparison, identical electrofishing sampling efforts in the Missouri River downstream from Great Falls commonly result in the capture of stonecats (P. D. Hamlin, Montana Fish, Wildlife and Parks, personal communications) Based on our results, we hypothesize that stonecat distributions have changed since the late 1800s due to the thermal influence of the three large reservoirs (Canyon Ferry, Hauser, and Holter Reservoirs) immediately upstream from our study area. In 2004 and 2005, July and August daily water temperatures upstream from Canyon Ferry Reservoir averaged 20.6 °C (measured at U. S. Geological Survey [USGS] gauging station 06054500), compared to 17.8 °C and 16.9 °C (measured at USGS gauging station 06066500) downstream from Holter Dam, respectively (USGS, unpublished data) Furthermore in the river upstream from Canyon Ferry Reservoir, water temperature reached 25.0 °C during 4 days in 2004 but maximum daily water temperature for the river downstream from Holter Dam only reached 20.0 °C in 2004 and 19 in 2005. The effect of large water-storage impoundments on downstream physical habitat and biological communities, i.e., the Serial Discontinuity Concept, has been well developed in the primary literature (Ward and Stanford 1983, 1995). We hypothesize that water temperature changes caused by upstream reservoirs may have limited distribution of stonecats to the lower 19-km of the study area.

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LITERATURE CITED

Brown, . J. D. 1971. Fishes of Montana. Big Sky Books, Montana State University, Bozeman, Montana.

Etnier, D. A. and W. C. Starnes. 1993. The fishes of Tennessee. University of Tennessee Press, Knoxville.

Coker, G. A., C. B. Portt, and C. K. Minns. 2001. Morphological and ecological characteristics of Canadian freshwater fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences number 2554.

Horton, T. B. and A. C. Strainer. 2008. Distribution and Population Characteristics of Burbot in the Missouri River, Montana; Based on Hoop Net, Cod Trap, and Slat Trap Captures. Pp. 201-211 *in* V. L. Paragamian and D. Bennett, editors, Burbot: ecology, management, and culture. Symposium 59. American Fisheries Society, Bethesda, MD

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, MD.

Paragamian, V. L. 2000. The effects of variable flows on burbot spawning migrations in the Kootenai River, Idaho USA, and Kootenay Lake, British Columbia, Canada after construction of Libby Dam. Pp. 111-123 *in* V. L. Paragamian and D. W. Willis, editors. Burbot biology, ecology and management. Publication number 1. Fisheries Management Section of the American Fisheries Society, Spokane, WA.

Pflieger, W. L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City, MO.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa.

Spence, C. R. 2000. A comparison of catch success between two styles of burbot traps in lakes. Pp. 165-170 *in* V. L. Paragamian and D. W. Willis, editors. Burbot biology, ecology and management. Publication number 1. Fisheries Management Section of the American Fisheries Society, Spokane, WA.

Trautman, M. B. 1981. The fishes of Ohio with illustrated keys, revised edition. Ohio State University Press, Columbus.

Walsh, S. J. and B. M. Burr. 1985. Biology of the stonecat, *Noturus flavus* (Siluriformes: Ictaluridae), in central Illinois and Missouri streams, and comparisons with Great Lakes populations and congeners. Ohio Journal of Science 85:85-96.

Ward, J. V. and J. A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pp. 29-42 *in* Dynamics of lotic ecosystems. Ann Arbor Science Publishers Inc., Ann Arbor, Michigan.

Ward, J. V. and J. A. Stanford. 1995. The serial discontinuity concept: extending the model to floodplain rivers. Regulated Rivers: Research and Management 10:159-168.

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MONITORING UNGULATE CARCASSES AND GRIZZLY BEAR SCAVENGING ON THE NORTHERN YELLOWSTONE WINTER RANGE

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ABSTRACT

Ungulate carcasses are an important food source for scavengers, including grizzly bear (*Ursus arctos horribilis*), in the Greater Yellowstone Ecosystem. Each spring since 1989, nine transect routes in the Gardiner Basin, Montana, have been used to monitor availability of ungulate carcasses. We surveyed these transects during March-May 2006 and also conducted a complete search for carcasses on important parts of the Northern Yellowstone Winter Range (NYWR) adjacent to Yellowstone National Park (YNP). Our goals were to determine 1) how count of ungulate carcasses on existing transects compared with more complete carcass counts along transects throughout the landscape and 2) document bear scavenging on the carcasses. Carcass density on existing transects was four times greater than on new transects, 0.8 vs. 0.2 carcasses/km, respectively. The original transects included areas where carcasses were most likely to be found and provided a good annual index of ungulate carcass availability. Starvation was the cause of death for 70 percent of recorded ungulates ($n = 106$). Contrary to findings inside YNP, we found very little evidence of grizzly bear predation or use of carcasses (1 of 106 carcasses) or total bear use (4 carcasses) in the Gardiner Basin. This may be due to a greater level of human disturbance or a lower density of bears on National Forest winter range compared to YNP winter range.

Key words: carcass, Gardiner Basin, grizzly bear, Northern Yellowstone Winter Range, scavenging, ungulates, *Ursus arctos horribilis*, winter mortality.

INTRODUCTION

To understand the dynamics of bears and ungulate populations, knowledge about predation and scavenging by bears is essential (Mattson 1997). Thus, it is important that management agencies consider ungulate carcass availability in their management strategies, including identification of human activities that influence access to carrion by bears, because human activities can influence spatial use by bears (Nellemann et al. 2007).

We envision a need for well-designed carcass surveys to monitor trends in carrion availability, including areas outside YNP. Despite the recent removal of the grizzly bear from the Endangered Species List, its population status and availability of food sources still need to be monitored closely. Inside YNP the Interagency Grizzly Bear Study Team (IGBST) has monitored spring ungulate carcass availability on the YNP portion of the Northern Yellowstone Winter Range since 1986 (Cherry 2007). To supplement this monitoring, the Gardiner Ranger District, Gallatin National Forest (GNF), initiated 9 carcass transects in the Gardiner Basin north of Y P, on the lowest portion of the NYWR, in 1989. The first

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goal of our study was to investigate whether these transects reflected carrion availability in the area.

A wide variety of organisms utilize carrion (DeVault et al. 2004). Facultative scavenging is a common strategy among vertebrates (Selva et al. 2005), and almost all vertebrate predators utilize carrion to some degree (DeVault et al. 2003). Recent investigations suggest that carrion use by vertebrates is a key ecological process (DeVault et al. 2003), and that carrion may account for a larger portion of the diet of some facultative scavengers than is now commonly assumed (DeVault and Rhodes 2002). Selva et al. (2005) suggested that scavenging by vertebrates is not a random process, but mediated by extrinsic factors and the scavengers' behavioral adaptations.

Selva et al. (2005) found that all 36 recorded scavenging species in their study in Poland (22 birds and 14 mammals) preferred predator-kills over animals that had died from other causes, and that almost all mammalian scavengers avoided non-ungulate carcasses. Many of the carnivorous species in the Greater Yellowstone Ecosystem (GYE), the area within and surrounding Yellowstone National Park (YNP) in the USA, rely on elk as their primary source of carrion (Gese et al. 1996). Coyotes (*Canis latrans*) are the most common scavenger on carcasses (Stahler et al. 2002, Weaver 1979). In addition, grizzly bears (*Ursus arctos horribilis*), black bears (*U. americanus*), and red foxes (*Vulpes vulpes*) utilize elk (*Cervus elaphus*) carrion available in the GYE as a result of predation or winter kill (Stahler et al. 2002).

The grizzly bear was listed as a "Threatened" species under the Endangered Species Act in the conterminous United States in 1975 (Glick 2005) and a recovery plan was prepared. All criteria set under the recovery plan were met and the GYE population was removed from the list of federally threatened species in March 2007 (Paige 2008).

Numerous ecological studies have been conducted on grizzly bears in the GYE. Studies of food habits have found substantial seasonal and yearly variation in diet (Mattson et al. 1991, Mattson and Reinhart 1997, Mattson et al. 2002a, Mattson et al. 2002b, Mattson 2004, Mattson et al. 2005). Although grizzly bears are entirely vegetarian in some ecosystems (Rode et al. 2001), they will usually eat meat given the opportunity, and they can be effective scavengers and predators (Cole 1972, Mattson 1997).

Several studies have pointed out the importance of carcasses to grizzly bears (Mealey 1975, Green et al. 1997, Mattson 1997, Wilmers and Stahler 2002). Most scavenging occurs during spring and is associated with the abundance and relative availability of different types of carrion on ungulate winter ranges (Mattson 1997, Wilmers et al. 2003). Grizzly bears in the GYE use ungulates to a greater extent than most grizzly and brown bears in North America (Mattson et al. 1991), and they receive substantial energy from ungulates through predation and scavenging (Green et al. 1997, Mattson 1997). Robbins et al. (2006) estimated that 80 percent of the annual energy intake of adult males came from animal protein. Mattson (1997) estimated that 95 percent of the energy required by Yellowstone's grizzly bears during the non-denning season comes from elk, bison (*Bison bison*), and moose (*Alces alces*) and that 70 percent of ungulate meat in their diet came from scavenging. Our second goal was to document the level of bear scavenging activity in the area adjacent to YNP.

STUDY AREA

The study was conducted in the Gardiner Basin on the Gardiner Ranger District, GNF (45°2'13"N, 110°45'50"W), situated northeast of Gardiner in southwestern Montana, USA. The study area was part of the 1530-km^2 NYWR, where ungulates winter in large aggregations along the Yellowstone River (Houston 1982), and includes most of the range outside of YNP. The NYWR is described by Houston (1979). It falls within the GYE, one of the largest intact ecosystems in the conterminous United States (USDA Forest Service 2008). The main streams running through the NYWR outside YNP are Palmer, Bear, Eagle, Phelps, Shaft House, Little Trail, Basset, Cedar, and Slip and Slide creeks. The study area (Fig. 1) was restricted to USDA Forest Service and state lands east and north of the Yellowstone River historically used by wintering ungulates.

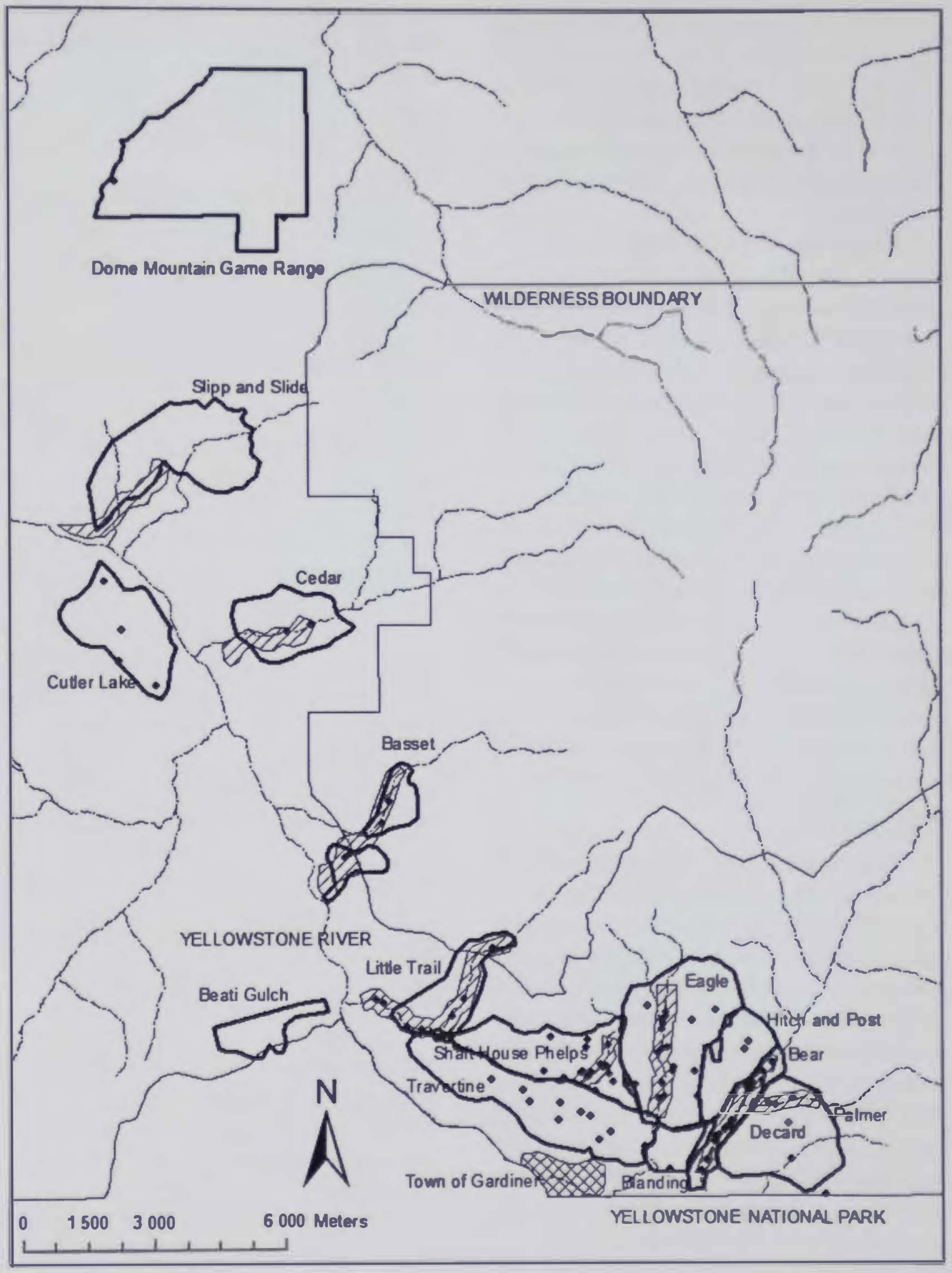

Figure 1. Map of the Gardiner Basin study area north of Yellowstone National Park showing boundaries of areas where landscape transects (solid thick lines) and original transects (polygons with stripes) were walked for the spring 2006 carcass survey. Black dots indicate carcass locations.

Elevation at the town of Gardiner, within the Gardiner Basin, is 1618 m. The average minimum temperature in Gardiner in January is -10 °C, and the average maximum temperature in July is 30 °C, annual average precipitation is 252 mm, and annual average snow fall is 635 mm. The highest amount of rainfall occurs in May and June (Western Regional Climate Center 2008). Precipitation increases and temperature decreases as elevation increases in the study area (Western Regional Climate Center 2008).

Vegetation in the Gardiner Basin consists primarily of big sagebrush (*Artemisia tridentata*) and grassland (dominated by blue-bunch wheatgrass, *Pseudoroegnaria spicatum*, and Idaho fescue, *Festuca idahoensis*) with scattered stands of Rocky Mountain juniper (*Juniperus scopulorum*) and limber pine (*Pinus flexilus*) at lower elevations, some quaking aspen (*Populus tremuloides*) at forest-grassland boundaries and in riparian areas, and Douglas-fir (*Pseudotsuga menziesii)* forests at mid-elevations. At higher elevations and on mid-elevation northern aspects, lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii)*, and subalpine fir (*Abies lasiocarpa*) are the dominant tree species.

METHODS

Each spring since 1989, nine transect routes have been examined in the Gardiner Basin to monitor the availability of ungulate carcasses for scavengers, usually by one person. Transects were generally oriented along waterways or followed existing trails along the major drainages in the Gardiner Basin. They were laid out by knowledgeable biologists to represent areas where wintering ungulates were presumed to congregate (and also, presumably, to die), and where bears were likely to forage on carrion. They were traveled on foot every 2 weeks from the first of March to the end of May. Ungulate mortality in YNP occurs mostly from March to May (Houston 1978, Schleyer 1983, Green et al. 1997, Mech et al. 2001).

We repeated these transects in 2006. One to three people walked the transects covering a linear distance of 23.0 km one or more times. Transects on which carcasses were recorded were re-run several times to record timing and extent of scavenging, resulting in a total distance examined of 64.2 km. Sampling intensity differed among drainages with more effort devoted to areas with higher carcass densities. These transects are hereafter referred to as *original transects*.

In addition to the original transects, we conducted an intensive search along a series of parallel lines, 200 m apart, that covered nearly all the ungulate winter range on public land within the study area to test the efficiency of the original survey technique. The systematic transect routes were oriented east–west or north–south, independently of drainage orientation. These additional transects included 126 lines across 15 major drainages (total length of 242.6 km). Green et al. (1997) indicated that, historically, carcass availability on the NYWR in YNP peaked the first half of April. This peak corresponded to the maximum accumulation of carcasses from starving animals before insects could reduce visibility of carcasses. Therefore, we conducted our searches between 15 April and 1 June. The systematic transects were sampled once, and are hereafter referred to as *landscape transects*.

For each carcass located on both types of transects, we recorded estimated time of death (winter or spring), species, sex, age, and cause of death. We also recorded site characteristics, including Universe Transverse Mercator (UTM) location, distance to forest edge, and cover. In addition, we described the site, and recorded if the carcass was visible from a road and whether or not the antlers had been removed from male ungulates and vestigial upper canine teeth ("ivories") from both male and female elk carcasses. Both antlers and upper canines of elk have monetary value and a large number of recreational hikers seek these out each year. Removal of antlers and teeth provides some indication of the level of human use of the area, which could be relevant in relation to grizzly bear use. We determined cause of death based on wounds on the carcass and evidence of predators, such as tracks, scats, or distinctive consumption patterns (Evans et al. 2006) and the condition of bone marrow in the metacarpus or metatarsus. Marrow fat is the last storage area of fat used by an animal in declining nutritional condition (Harris 1945). According to Harris (1945) signs of malnutrition are first evident in the tibia, and last in the metacarpus. If the bone marrow showed signs of starvation (red and jelly-like) (Greer 1968), the signs of predators were assumed to be from scavenging rather than predators. We made an effort to identify the appropriate scavenger(s). Scavenging rates were determined by repeated visits at the carcass sites on the original transects, and were approximate. We did not conduct any necropsy, except examination of the bone marrow. We were unable to calculate biomass consumed with our survey methodology.

To allow for an analysis of relative carcass densities among cover types related to cover type availability, we measured length of each cover type along each transect using Global Positioning System (GPS) and Geographic Information Systems (GIS) technology. Cover types were divided in to 21 categories (Table 1) following Yonge (2001). Because many cover types had too few carcasses for efficient analysis, cover types were combined into four vegetation groups: riparian, open vegetation, open forest, closed forest (Yonge 2001) (Table 1). This categorization was somewhat arbitrary, but it corresponded to vegetation structural features that have been demonstrated to be important for wildlife in the Yellowstone ecosystem (Mattson and Despain 1985).

Every time a change in cover type occurred along a transect (original or landscape), we marked the UTM coordinate at the point of the change. We used the GIS tool ET GeoWizards 9.6 (ET SpatialTechniques 2008) to create lines in Arc View (ESRI 2006) from the UTM coordinates. We calculated the distance traveled within each cover type using Hawth's analysis tools (Beyer 2004). We compared the number of carcasses found/km of transect and the distributions of carcasses among cover types between the original and landscape transects.

We used the statistical package SPLUS (MathSoft Inc. S-Plus 2000) for statistical analyses. Differences in distribution of data sets among categorical variables, e.g., vegetation groups, were determined using Pearson Chi-square or Fisher exact tests when samples in individual cells were below acceptable numbers.

RESULTS

Data collection involved 74 full days in the field. We examined a total of 26.6 km of transects; 23.0 km of original transect (traveled multiple times, for a total of 64.2 km) and 242.6 km of landscape transects. We found 106 carcasses, 67 of mule deer (hereafter referred to as deer) and 39 of elk. We found 51 (30 deer and 21 elk) and 55 (37 deer and 18 elk) carcasses on the original and landscape transects, respectively. We found most (69) carcasses at Bear Creek, Eagle Creek, the Shaft House, Phelps Creek area, and Travertine Flats (Fig. 1).

The original transects had densities of carcasses that were about four times greater than the landscape transects ($\chi^2 = 45.35$, $P < 0.001$, 0.8 versus 0.2 carcasses/km, respectively). The pattern was similar for elk (0.33 versus 0.07 carcasses/km, $\chi^2 = 23.42$, $P < 0.001$) and deer (0.47 versus 0.15 carcasses/km, $\chi^2 = 21.42$, $P < 0.001$). Proportions of cover type groups differed between the two types of transect. The landscape transects had a lower proportion of total transect length in the riparian and closed forest groups and higher proportions of transects in the open sage/grass and open forest groups than original transects (χ^2 without Yate's correction: = 9.9257, df = 3, $P = 0.0192$; Table 1).

Contrary to our expectations, we found only four instances of bear scavenging activity, and determined only one to involve a grizzly bear (Table 2). In addition to one documented wolf kill, we found three additional elk in which wolf

Table 1. Segment lengths and carcasses located by cover classes (Mattson and Despain 1985, Yonge 2001) and groups (consolidation of classes into groups based on vegetation structure) on transects established in 1989 and walked annually to monitor carcasses in the Gardiner Basin (original transects) and transects covering the entire winter range outside Yellowstone National Park in the Gardiner Basin, Montana, walked only in 2006 (landscape transects). Data include only carcasses located in spring 2006.

Cover class/*group*	Landscape transects			Original transects		
	Segment length(m)	% of total transect	Carcasses	Segment length(m)	% of total transect	Carcasses
Riparian shrub	884		0	2,707		3
Cottonwood	678		1	55		0
Aspen	8,147		1	1,369		9
Riparian group	**9,709**	**4%**	**2**	**4,131**	**18%**	**12**
Sage/grass	188,814		42	5,971		6
Meadow	0		0	0		0
Tallus	3,973		2	30		0
Open vegetation group	**192,787**	**80%**	**44**	**6,001**	**26%**	**6**
Juniper-sage	3,466		2	530		3
Douglas fir - sage	4,491		2	0		0
Open conifer	15,544		1	780		0
Open aspen/conifer	509		1	195		2
Open forest group	**24,010**	**10%**	**6**	**1,505**	**7%**	**5**
Juniper	1,440			483		3
Juniper-DF 2 or 3[1]	0			0		0
DF2	3,134			1,624		7
DF3	2,487		0	2,102		13
SF	254		0	1,159		1
DF-aspen	951		0	1,156		1
DF-cottonwood	385		0	1,720		1
LP3	3,521		0	0		0
DF3/riparian	229		0	1,454		1
DF	3,393		2	1,616		1
Aspen/SF	328			0		0
Closed forest group	**16,122**	**7%**	**3**	**11,314**	**49%**	**28**
Total transect length	***242,628***		***55***	***22,951***		***51***

[1] DF = Douglas-fir, SF = spruce-fir, LP = lodgepole pine; 2= mature forest 100-300 years post disturbance, 3 = climax forest 300+ years post disturbance

predation was the probable cause of death. Of the 106 carcasses on both original and landscape transects, 70 percent were winterkills (Table 3).

Antlers and/or upper canines had been removed from 77 percent of male elk (including both transect sets). Antlers had been removed from 33 percent of the antlered deer. No carcasses were visible from roads on the original transects. On the landscape transects 13 carcasses (7 deer and 5 elk) were visible from a road. Fifteen percent of the carcasses we found had not been fed on by mammalian scavengers.

Table 2. Carcasses that showed evidence of predation and/or scavenging when located on landscape and original transects in the Gardiner Basin, Montana, during spring 2006.

Scavenger/predator	**Carcass species on:** Landscape transects		Original transects		All transects
	Elk	*Deer*	*Elk*	*Deer*	*Elk and Deer*
Mountain lion[1]	0	2	0	5	7
Bear	0	0	4	0	4
Wolf[1]	0	0	1	0	1
Canid (coyote or wolf)	13	19	10	12	54
Birds/maggots	1	0	2	4	7
Unknown	4	14	0	6	24
Not consumed	0	2	4	3	9
Total	**18**	**37**	**21**	**30**	**106**

[1] Lions and wolves likely killed most or all carcasses attributed to them.

Table 3. Causes of death for elk and mule deer located on landscape and original transects in the Gardiner Basin, Montana, spring 2006. Cause of death was assigned based on patterns of carcass disturbance and bone marrow examination.

Cause of death	**Landscape transects**		**Original transects**		**Total carcasses**	
	Elk	*Deer*	*Elk*	*Deer*	*N*	*Percent*
Mountain Lion	0	2	0	5	7	6.6
Wolf	0	0	1	0	1	0.9
Unknown canid	1	0	0	0	1	0.9
Unknown predation	3	3	0	2	8	7.5
Hunter	0	1	0	0	1	0.9
Winterkill	12	25	17	20	74	69.8
Unknown	2	6	3	3	14	13.2
Total	**18**	**37**	**21**	**30**	**106**	**100.0**

DISCUSSION

Carcass Distribution on Landscape and Original Transects

The landscape transects, which mirrored vegetation cover group availability better than the original transects, had a lower proportion of total transect length in the riparian and closed forest cover classes and higher proportions of transects in the open vegetation and open forest cover classes than original transects. Both transect sets included segments in all of the major cover classes available on the NYWR. Relative density of carcasses was approximately four times greater on original transects than on landscape transects (0.8 vs. 0.2 carcasses/km, respectively). Because of the high proportion of open vegetation that provides for greater visibility of carcasses on the landscape transects, we assumed that the number of carcasses we recorded on landscape transects was close to the true number available in spring 2006.

Overall, these data indicate that the original transects provided a reasonable (but not proportionate) coverage of available winter range habitat types and that they sampled areas where carcasses might more likely be found than on the winter range as a whole. Use of the original transect set should, therefore, provide a reasonable index of carcass availability among years rather than investing the large amount of time required to cover the entire winter range.

Scavenging Intensity

We found very little evidence of bear use of ungulate carcasses and only one documented grizzly bear scavenging event. As early as 1974, Houston (1978) conducted carcass counts on the NYWR inside YNP and standardized carcass counts have been conducted inside YNP since 1986 (Cherry 2007). In 2006, 73 carcasses (elk and bison), or 0.49 carcasses/km, were found along 155.3 km of transects on the NYWR inside the park. Of these, 24 (33%) had been visited by bears (Podruzny and Gunther 2007). We found a carcass density of 0.2 and 0.8 carcasses/km on the landscape and original transects, respectively. Cherry (2007) argued that the only consistent index of carcass availability has been the number of carcasses/km and that no attempt has been made to estimate density. The routes in YNP were established based on knowledge about the likelihood of finding carcasses and where bears are known to forage in spring, not on a probability-based sampling method (Cherry 2007). This method has similarities to the sampling method we used on the original transects. Our data suggest that bear use of carcasses on the NYWR was much higher inside than outside YNP even though all of our study area was within grizzly bear distribution range (Schwartz et al. 2006).

There may be many reasons for the differences in carcass use. First, the level of human presence in spring is probably higher in the Gardiner Basin than inside YNP, as suggested by the large percentage of antlers removed from carcasses. Taking any naturally occurring object, including antlers, out of YNP is prohibited (USDI National Park Service 2008), so carcasses are more likely to be left undisturbed inside YNP. Mattson et al. (1987) found that the proportion of ungulate carcasses used by grizzly bears in YNP appeared to be influenced at a distance of 200–300 m from primary roads, and Green et al. (1997) determined that grizzly bear use of carcasses in YNP was lower within 400 m of a road and within 5 km of a major recreational development. Also, grizzly bear responses to roads depend on the type of human activity along the roads (Wielgus et al. 2002). In the Gallatin National Forest, public land is managed under a multiple use mandate and, as such, a wider variety of human activities are allowed and public use is much less restricted than in YNP (USDA Forest Service 1982). However, grizzly bears can alter their diurnal behavioral pattern in response to human presence (Mueller et al. 2004). An alternate explanation for the lower scavenging rate by bears, particularly grizzly bears, on the NYWR outside YNP is lower bear density. This area is at the edge of the expanding grizzly bear distribution in the GYE (Schwartz et al. 2006). Bear population density tends to be low in the peripheral areas of expanding populations (Swenson et al. 1998). Many of the carcasses that had been fed on by mammals were only partially consumed and 15 percent had not been fed on by mammalian scavengers. Thus, the great abundance of carcasses in YNP might have satiated scavengers, so they did not require carrion outside the park, or total scavenger density may have been lower outside YNP, due to trapping and/or hunting or because some scavengers avoided areas where human-induced mortality might occur.

Our study was not designed to compare grizzly bear use of carcasses on these very differently managed landscapes, but such a study would be useful in understanding how grizzly bears deal with human presence and would be valuable for land managers charged with creating land-use regulations to minimize human impact on grizzly bear populations.

CONCLUSIONS AND MANAGEMENT IMPLICATION

We conclude that the original transects initiated by the Gardiner Ranger District in 1989 provide a reasonable index to annual carcass abundance in the NYWR north of YNP. In areas where meat constitutes a major part of brown bears' diet, managers should take the availability and perpetuation of these resources into consideration (Hilderbrand et al. 1999). Variation in the availability of this important food source could affect the viability of populations of grizzly bears and other scavengers. The spatial and temporal distribution of carcasses must be addressed in management strategies, if the goal is conservation of specific wildlife populations or healthy ecosystems

(Hilderbrand et al. 1999). Thus, it is essential for managers to track long-term trends in the availability of carcasses. We, therefore, recommend continued monitoring of carcass distribution on the NYWR outside YNP using the original transects.

In spring 2006, 33 percent of the carcasses found on the NYWR in YNP had been visited by bears, compared with only 4 percent outside YNP. This may be due to grizzly bears responding to more ground-based human activities outside YNP, lower densities of bears outside YNP, or a combination of the two factors.

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LITERATURE CITED

Beyer, H. L. 2004. Hawth's analysis tools for Arcgis. Available at http://www.Spatialecology.Com/Htools.

Cherry, S. 2007. Monitoring ungulate carcasses and spawning cutthroat trout. P. 55 *in* C. C. Schwarts, M. A. Haraldson, and K. West, editors. Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 2006. U.S. Geological Survey, Bozeman, MT.

Cole, G. F. 1972. Grizzly bear elk relationships in Yellowstone National Park. Journal of Wildlife Management 36:556-561.

DeVault, T. L., I. L. Brisbin, and O. E. Rhodes. 2004. Factors influencing the acquisition of rodent carrion by vertebrate scavengers and decomposers. Canadian Journal of Zoology 82:502-509.

DeVault, T. L. and O. E. Rhodes. 2002. Identification of vertebrate scavengers of small mammal carcasses in a forested landscape. Acta Theriologica 47:185-192.

DeVault, T. L., O. E. Rhodes, and J. A. Shivik. 2003. Scavenging by vertebrates: behavioral, ecological, and evolutionary perspectives on an important energy transfer pathway in terrestrial ecosystems. Oikos 102:225-234.

ESRI. 2006. Arc GIS Version 9.1. Environmental Systems Research Institute Inc., Redlands, CA.

ET SpatialTechniques. 2008. ET Geowizards, Available at http: Www.Ian-Ko.Com

Evans, S. B., L. D. Mech, P. J. White, and G. A. Sargeant. 2006. Survival of adult female elk in Yellowstone following wolf restoration Journal of Wildlife Management 70.13 1378.

Gese, E M., R L Ruff and R L Crabtree 1996. Foraging ecology of coyote (*Canis latrans*): the influence of extrinsic factor and a dominance hierarchy. Canadian Journal of Zoology 74 769 783

Glick, D. 2005. Back from the brink Smithsonian 36:54-62.

Green, G. I., D. J. Mattson, and J M. Peek. 1997. Spring feeding on ungulate carcasses by grizzly bears in Yellowstone National Park. Journal of Wildlife Management 61:1040-1055.

Greer, K. R. 1968. A compression method indicates fat content of elk (wapiti) femur marrows. Journal of Wildlife Management 32:747-751.

Harris, D. 1945. Symptoms of malnutrition in deer. Journal of Wildlife Management 9:319-322.

Hilderbrand, G. V., S. G. Jenkins, C. C. Schwartz, T. A. Hanley, and C. T. Robbins. 1999. Effect of seasonal differences in dietary meat intake on changes in body mass and composition in wild and captive brown bears. Canadian Journal of Zoology 77:1623-1630.

Houston, D. B. 1978. Elk as winter-spring food for carnivores in northern Yellowstone National Park. Journal of Applied Ecology 15:653-661.

Houston, D. B. 1979. The northern Yellowstone elk - winter distribution and management. Pp. 263-272 *in* M S.

Boyce and L. J.Hayden, editors. North American elk: Ecology, behavior and Management, University of Wyoming, Laramie.

Houston, D. B. 1982. The northern Yellowstone elk: ecology and management. MacMillan Publishing Co., New York, NY.

MathSoft Inc. S-Plus. 2000. Data Analysis Products Division, Mathsoft. Seattle, WA.

Mattson, D. J. 1997. Use of ungulates by Yellowstone grizzly bears - *Ursus arctos*. Biological Conservation 81:161-177.

Mattson, D. J. 2004. Exploitation of pocket gophers and their food caches by grizzly bears. Journal of Mammalogy 85:731-742.

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977-1987. Canadian Journal of Zoology 69:1619-1629.

Mattson, D. J. and D. G. Despain. 1985. Grizzly bear habitat component mapping handbook for the Yellowstone Ecosystem. Forest Service, Yellowstone National Park, WY. 37 pp.

Mattson, D. J., R. R. Knight, and B. M. Blanchard. 1987. The effects of developments and primary roads on grizzly bear in Yellowstone National Park, Wyoming. International Conference for Bear Research and Management 7:259-273.

Mattson, D. J., M. G. French, and S. P. French. 2002a. Consumption of earthworms by Yellowstone grizzly bears. Ursus 13:105-110.

Mattson, D. J., S. R. Podruzny, and M. A. Haroldson. 2002b. Consumption of fungal sporocarps by Yellowstone grizzly bears. Ursus 13:95-103.

Mattson, D. J., S. R. Podruzny, and M. A. Haroldson. 2005. Consumption of pondweed rhizomes by Yellowstone grizzly bears. Ursus 16:41-46.

Mattson, D. J., and D. P. Reinhart. 1997. Excavation of red squirrel middens by grizzly bears in the whitebark pine zone. Journal of Applied Ecology 34:926-940.

Mealey, S. P. 1975. The natural food habits of free ranging grizzly bears in Yellowstone National Park 1973-1974. M.S. thesis, Montana State University, Bozeman.

Mech, L. D., D. W. Smith, K. M. Murphy, and D. R. MacNulty. 2001. Winter severity and wolf predation on a formerly wolf-free elk herd. Journal of Wildlife Management 65:998-1003.

Mueller, C., Herrero, S., and M. L. Gibeau, 2004. Distribution of subadult grizzly bears in relation to human development in the Bow River Watershed, Alberta. Ursus 15:35-47.

Nellemann, C., O.-G. Støen, J. Kindberg, J. E. Swenson, I. Vistnes, G. Ericsson, J. Katajisto, B. P. Kaltenborn, J. Martin, and A. Ordiz. 2007. Terrain use by an expanding brown bear population in relation to age, recreational resorts and human settlements. Biological Conservation 138:157-165.

Paige, C. 2008. State of the grizzly. Montana Outdoors, Magazine of Montana Fish, Wildlife and Parks. March-April 2008. Available at http://fwp.mt.gov/mtoutdoors/HTML/articles/2008/StateOfTheGrizzly.htm

Podruzny, S. and K. Gunther. 2007. Spring ungulate availability and use by grizzly bears in Yellowstone National Park. In C.C. Schwarts, M.A. Haraldson, and K. West, editors. Yellowstone Grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 2006. U.S. Geological Survey, Bozeman, MT. p 19-20.

Robbins, C. T., C. C. Schwartz, K. A. Gunther, and C. Servheen. 2006. Grizzly bear nutrition and ecology studies in Yellowstone National Park. The Interagency Grizzly Bear Study Team. Yellowstone Science 14:1-8 Available at http://www.nrmsc.usgs.gov/files/norock/products/GrizzlyBearNutrition-Ecology.

Rode, K. D., C. T. Robbins, and L. A. Shipley. 2001. Constraints on herbivory by grizzly bears. Oecologia 128:62-71.

Schleyer, B. O. 1983. Activity patterns of grizzly bears in the Yellowstone ecosystem and their reproductive behavior, predation and the use of carrion. M.S. thesis, Montana State University, Bozeman.

Schwartz, C. C., M. A. Haroldson, K. A. Gunther, and D. Moody. 2006. Distribution of grizzly bears in the Greater Yellowstone Ecosystem in 2004. Ursus 17:63-66.

Selva, N., B. Jedrzejewska, W. Jedrzejewski, and A. Wajrak. 2005. Factors affecting carcass use by a guild of scavengers in European temperate woodland. Canadian Journal of Zoology 83:1590-1601.

Stahler, D., B. Heinrich, and D. Smith. 2002. Common ravens, *Corvus corax*, preferentially associate with grey wolves, *Canis lupus*, as a foraging strategy in winter. Animal Behaviour 64:283-290.

Swenson, J. E., F. Sandegren, and A. Söderberg. 1998. Geographic expansion of an increasing brown bear population: evidence for presaturation dispersal. Journal of Animal Ecology 67:819-826.

USDA Forest Service. 1982. Gallatin National Forest, forest plans. Gallatin National Forest, Bozeman, MT. 180 pp.

USDA Forest Service. 2008. Gallatin National Forest. Welcome to the Gallatin National Forest. Gallatin National Forest, Bozeman, MT. Available at http://www.fs.fed.us/r1/gallatin/

USDI National Park Service. 2008. Yellowstone National Park, Available at http://Home.Nps.Gov/Yell/Planyourvisit/Impact.Htm.

Weaver, J. L. 1979. Influence of elk carrion upon coyote populations in Jackson Hole, Wyoming. Pp. 152-157 *in* M.S Boyce and L.J.Hayden, editors. North American elk: ecology, behavior and management, University of Wyoming, Laramie.

Western Regional Climate Center. 2008. Montana climate summaries. National Oceanic and Atmospheric Administration, Accessed June 27, 2008. Available at http://www.wrcc.dri.edu/summary/climsmmt.html

Wielgus, R. B., P. R. Vernier, and T. Schivatcheva. 2002. Grizzly bear use of open, closed, and restricted forestry roads. Canadian Journal of Forest Research 32:1597-1606.

Wilmers, C. C., R. L. Crabtree, D. W. Smith, K. M. Murphy, and W. M. Getz 2003. Trophic facilitation by introduced top predators: grey wolf subsidies to scavengers in Yellowstone National Park Journal of Animal Ecology 72:909-916

Wilmers, C. C. and D. R. Stahler. 2002. Constraints on active-consumption rates in gray wolves, coyotes, and grizzly bears. Canadian Journal of Zoology 80:1256-1261.

Yonge, S. R. 2001. The ecology of grizzly bears and black bears in the Cooke City, Montana area. M.S. thesis, Montana State University, Bozeman. 88 pp.

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SEASONALITY OF POTENTIAL STEM PHOTOSYNTHESIS / RESPIRATION IN FOUR HARDWOODS

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ABSTRACT

We observed an increasing reflectance of stems of four hardwoods in early spring. We hypothesized that it indicates an acclimation to spring conditions, likely associated with increased stem photosynthetic potential which is followed by re-acclimation in the fall to winter conditions To test for changes in stem photosynthetic and respiratory capacity across seasons we contrasted, under laboratory conditions favorable to photosynthesis, CO evolution rates of hardwood stems acclimated to field conditions of winter, spring, summer and fall The four species studied included two that brighten strongly in spring [red-osier dogwood (*Cornus sericea*), brittle willow (*Salix fragilis*)] and two that brighten less [quaking aspen (*Populus tremuloides*), and black cottonwood (*P. trichocarpa*)]. Stem photosynthesis fixed, on average, 90 percent of carbon lost through respiration. We hypothesize that additional unmeasured photosynthesis is also occurring deeper within the stem. In all four species photosynthetic capacity increased in spring/summer and fell through fall to winter. In winter potential for photosynthesis fell markedly in both aspen and cottonwood and was eliminated in dogwood and willow. Responses of dogwood and willow provide the first known example of a complete down-regulation of stem photosynthesis in winter Selective and selection-neutral hypotheses for this phenomenon are offered, i.e., that cessation of photosynthesis in winter has either been randomly fixed in shrubs (selection neutral) or created by selection of grazing animals against winter photosynthesis (palatability) in low shrubs greater than in trees with inaccessible twigs (natural selection). In contrast to photosynthesis, the potential for stem respiration appeared in all species and all seasons, and was usually lowest in winter and was highest in spring/summer.

Key words: acclimation, bark photosynthesis, browse, *Cornus sericea, Populus tremuloides, Populus trichocarpa, Salix fragilis,* stem photosynthesis, stem respiration

INTRODUCTION

Stems of some hardwoods, especially willow (*Salix*) and dogwood (*Cornus*) significantly brighten, or "glow," in early spring. We speculate that increased reflectance indicates acclimation to spring/summer conditions and a marked increase in stem photosynthesis, followed in the subsequent fall by re-acclimation to winter conditions. Thus, we tested the hypothesis that photosynthetic potential of these stems increases from winter to spring and declines again with oncoming winter. We considered two hardwood species which brighten strongly [red-osier dogwood (*Cornus sericea*) and brittle willow (*Salix fragilis)*] and two with less noticeable brightening [quaking aspen (*Populus tremuloides*), and black cottonwood (*P. trichocarpa*)].

Stem photosynthesis is important in other species. A capacity for stem photosynthesis has been shown in at least 36 plant families (Pfanz and Aschan 2001). In woody plants it is conducted by chloroplasts present in the phloem, xylem rays, pith and cork cambium (Aschan and Pfanz 2003, Tesky et al. 2008). Its importance is suggested by the fact that the bark of aspen

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may contain 42 percent of the chlorophyll present (Kharouk et al. 1995). Seasonal variation in stem photosynthesis has been observed in many species including quaking aspen (Foote and Schaedle 1976), grape (*Vitis*) (Ortoidze et al. 1988), lilac (*Syringa*) (Pilarski, 1990), beech (*Fagus*) (Damesin 2003), and alder (*Alnus*), ginkgo (*Ginkgo*), spruce (*Picea*), pine (*Pinus*) and oak (*Quercus*) (Gerveiller et al. 2007). Stem photosynthesis changes with variation in stem chlorophyll concentration (Aschen and Pfanz 2003, Tesky et al. 2008), thus, paralleling our observation of changes in brightness. Photosynthesis in woody stems can contribute significantly to total plant carbon gain (reviewed in Aschan and Pfanz 2003, Tesky et al. 2008), even 50 percent of total photosynthesis of plants with short leafy seasons, e.g., those of deserts (Comstock et al. 1988) and high elevations (Kyte 1975).

To test our hypothesis, we contrasted potential cross-bark CO_2 flux (CO_2 evolution to physiologists) of stems of four field-acclimatized hardwood species among the four seasons. Measurements were made in the laboratory under carefully controlled conditions.

MATERIALS AND METHODS

Twig Samples

Twigs were collected along Mathew Byrd Creek, Bozeman, MT [latitude 45°40', longitude 111°3', elevation 1455 m. Red-osier dogwood, brittle willow, quaking aspen and black cottonwood collections were made from single mature individuals. Collections were made across the four seasons of 1991-1992. A single individual of each species was sampled to eliminate potentially confusing site effects. While the lack of replication, due to limited resources, of in-season measurements prevented evaluation of variation in stem photosynthesis/respiration within species, we gained generality among species by demonstrating parallel cross-species behavior. Thus, similarity of response among species demonstrated parallel behavior. Leaves and buds were removed from the twigs to focus measurements on metabolism of current-year stems. To minimize the effects of wound respiration, i.e., to allow healing, all leaves and/or buds were removed from the most recent year's growth of the twigs one week before measurement.

Measurement of Photosynthesis and Respiration

We collected six twigs of each species for each run: five for measurement of CO_2 evolution, and one (a 'dummy') that was used only for monitoring temperature. The metabolism of current year's bark of each twig was measured in its individual chamber, a 200-ml glass test tube. Each test tube was closed with a three-hole stopper: one hole held the twig, and the two remaining holes allowed for air inflow and outflow. A fourth hole in the stopper of the dummy held a copper-constantan thermocouple that measured twig temperature. All six chambers were submerged in a water bath to provide temperature control. If any portion of the stem contained wood from previous year's growth it was masked with Parafilm® to minimize the influence of older internodes.

We measured CO_2 evolution first in the dark (respiration) and then in the light (simultaneous respiration and photosynthesis). Thus, before measuring respiration, we covered the water bath and allowed CO_2 evolution (respiration) to equilibrate for 10 min in the dark. When the respiration measurement was completed, we uncovered and illuminated the water bath. After stabilizing in the light (~20 min), twig CO_2 evolution was measured again with an Analytical Development Company (ADC®) infrared gas analyzer (IRGA). A pump delivered air (160 cm^3 min^{-1}) to each chamber and the air return line passed through the IRGA.

To allow comparison of twig and season rates, we expressed CO_2 evolution as a rate, i.e., μmole CO_2 m^{-2} sec^{-1}. The area of each stem was calculated by summing length x diameter x π across all exposed internodes. Larcher (1995) defined gross photosynthesis as CO_2 evolution$_{dark}$ - CO_2 evolution$_{light}$. A two-tailed *t*-test for paired data (Box et al. 1978) was used to determine whether the treatment (light) increased or decreased CO_2 evolution significantly.

Conditions

In testing for this change in photosynthetic/respiratory 'potential,' we have measured plant performance under a set of lab conditions with no intention of determining actual photosynthesis/respiration rates, or their integral, over the diversity of conditions appearing in the field during the year. To measure 'potential' photosynthesis and respiration, we needed to keep the twigs moist, warm (20 °C), and either dark or light saturated. Procedures for maintaining these conditions follow. First, to insure that the twigs were never dehydrated, they were excised under water on the day of measurement and the cut ends were kept immersed during transport to the laboratory. Approximately 1 hr after cutting, twigs were re-cut underwater to 20- to 25-cm lengths and kept underwater. Thus, cut ends were immersed during the entire experiment. Second, stem surface temperature was held at 20 °C by adding hot or cold water to the water bath surrounding the chambers to adjust twig temperatures. Twig temperature was read with a thermocouple inserted just under the bark, and near the midpoint of the dummy twig in each series. Third, the twigs, and their chambers, were held at an angle of 30° to the light by a test tube rack fastened inside the water bath. They were illuminated with a 6500W xenon lamp (Atlas Electric) which delivered 3200 umol m^{-2} sec^{-1} (~1300 ft-c) measured at an angle of 30° to the light. The spectrum of this lamp is very similar to daylight. Light saturation for aspen twig bark is between 800 ft-c (winter) and 1400 ft-c (summer, Foote and Schaedle 1976). Thus, we measured gross photosynthesis at or near natural light saturation in all cases.

Data Analysis

Differences between dark and light CO_2 evolution (gross photosynthesis) were determined using a paired *t*-test (Sigma Stat 3.0 for Windows 2003). Because two of the gross photosynthesis data sets were not normally distributed, we used a Kruskal-Wallis analysis of variance (ANOVA) on ranks to determine differences in gross photosynthesis between species within seasons (Sigma Stat 3.0 for Windows 2003). Differences were considered significant at $\alpha = 0.05$. Regression of gross photosynthesis vs. dark respiration were made using Sigma Plot 8.0 for Windows (2003).

RESULTS

We observed three patterns in potential stem photosynthesis. First, potential photosynthesis increased from winter to spring/summer and fell through fall to winter (Table 1, Fig. 1). The trend is statistically significant for three species. Though the trend is weaker in Aspen, where summer and fall photosynthesis were equal aspen's photosynthesis also declined from summer/fall to winter. During spring, summer and fall the stems of all species had relatively high and constant capacities for photosynthesis under ideal conditions (high light, water available and 25 °C). Second, photosynthesis, on average, compensated for 90 percent of respiration across all species and seasons. Full compensation was rare. Among the six replicates in the four seasons studied, i.e., 24 cases/species, four individual stems demonstrated net photosynthesis by compensating for respiration (negative light CO_2 evolution). We observed full compensation in aspen, cottonwood, and willow in summer and dogwood in spring (data not shown). Third, the potential for net photosynthesis for aspen and cottonwood was significantly reduced in winter and that of dogwood and willow was eliminated.

Respiratory potential, in contrast to photosynthetic, occurred at 20 °C in all seasons. Like photosynthesis, it was lowest in winter, except for willow (Table 1). The observed rates showed no seasonal pattern consistent across species. The respiratory potential of aspen, cottonwood and dogwood was greatest in spring/summer and least in winter. Willow respired most in summer and least in fall.

Table 1. Cross-season photosynthesis and respiration of four hardwood species.

Species	Season	Dark CO_2 evolution ($\mu mol\ m^{-2}\ s^{-1}$)	Light CO_2 evolution ($\mu mol\ m^{-2}\ s^{-1}$)	Gross photosynthesis ($\mu mol\ m^{-2}\ s^{-1}$)[1]	*p*-value for paired t-test (dark vs. light)[2]
Red-osier Dogwood	Winter	0.48 ± 0.01	0.52 ± 0.02	**-0.04 ± 0.02**[3]	0.09[4]
	Spring	0.76 ± 0.03	0.14 ± 0.06	0.63 ± 0.05	<0.001
	Summer	1.10 ± 0.06	0.15 ± 0.04	0.96 ± 0.08	<0.001
	Fall	0.53 ± 0.03	0.20 ± 0.05	0.33 ± 0.04	<0.001
Quaking Aspen	Winter	0.81 ± 0.18	0.29 ± 0.15	0.52 ± 0.04	<0.001
	Spring	1.38 ± 0.07	0.23 ± 0.07	1.15 ± 0.07	<0.001
	Summer	0.86 ± 0.03	0.14 ± 0.07	0.72 ± 0.07	<0.001
	Fall	1.14 ± 0.08	0.23 ± 0.03	0.92 ± 0.08	<0.001
Black Cottonwood	Winter	0.81 ± 0.06	0.30 ± 0.04	0.50 ± 0.03	<0.001
	Spring	1.47 ± 0.09	0.39 ± 0.12	1.07 ± 0.18	<0.001
	Summer	1.38 ± 0.10	0.22 ± 0.10	1.16 ± 0.18	<0.001
	Fall	1.21 ± 0.04	0.24 ± 0.12	0.97 ± 0.06	<0.001
Brittle Willow	Winter	1.59 ± 0.05	1.71 ± 0.01	**-0.11 ± 0.04**[3]	0.06[4]
	Spring	1.17 ± 0.07	0.69 ± 0.05	0.48 ± 0.09	<0.001
	Summer	1.96 ± 0.18	0.24 ± 0.22	1.73 ± 0.13	<0.001
	Fall	1.28 ± 0.05	0.75 ± 0.15	0.53 ± 0.09	<0.004

[1] Gross photosynthesis = CO_2 evolution$_{dark}$ - CO_2 evolution$_{light}$. Data are means ± 1 SEM ($n = 6$).

[2] A two-tailed t-test for paired data was used to determine if CO_2 evolution was significantly different between light and dark.

[3] **Bolded** entries in dogwood and willow indicate no net photosynthesis in winter.

[4] Differences in CO_2 evolution$_{dark}$ - CO_2 evolution$_{light}$ are not significantly different from zero at $\alpha = 0.05$.

Aspen and cottonwood had higher gross photosynthetic potential than dogwood and willow (the shrubs) during all seasons except summer. In summer gross photosynthesis was significantly higher in willow than the other species. In fall, winter, and spring, gross photosynthesis was significantly higher for aspen and cottonwood than for dogwood and willow (Fig. 1). In winter both aspen and cottonwood maintained the ability to photosynthesize, although gross photosynthesis for dogwood and willow did not significantly differ from zero, which indicated a complete down-regulation of photosynthesis in these two species.

Regression of potential gross photosynthesis vs. dark respiration across all data points yielded a slope of 0.71 ($r^2 = 0.35$; Fig. 2). When the two data points representing the lack of winter photosynthesis in dogwood and willow were removed, the regression slope increased to 0.90 ($r^2 = 0.73$). This indicates that, on average, cross-bark photosynthesis compensates for ~ 90 percent of respiratory CO_2 escaping.

DISCUSSION

We have repeatedly observed that twigs of dogwood and willow brighten in spring. We hypothesized that the "glow" indicated acclimation to spring/summer conditions and the re-initiation of photosynthesis. To test for this change in photosynthetic/ respiratory 'potential,' we measured plant performance under a set of laboratory conditions (full sun, adequate water and 20 °C) and without any intention of determining actual photosynthesis/respiration rates or their integral over the diversity of conditions appearing in the field during the year. Our data supported this hypothesis for two mostly shrubby genera (dogwood and willow) and simultaneously rejects it for aspen and cottonwood trees. The brightening in dogwood and willow, which are visibly red and yellow, respectively, probably resulted from increased levels of

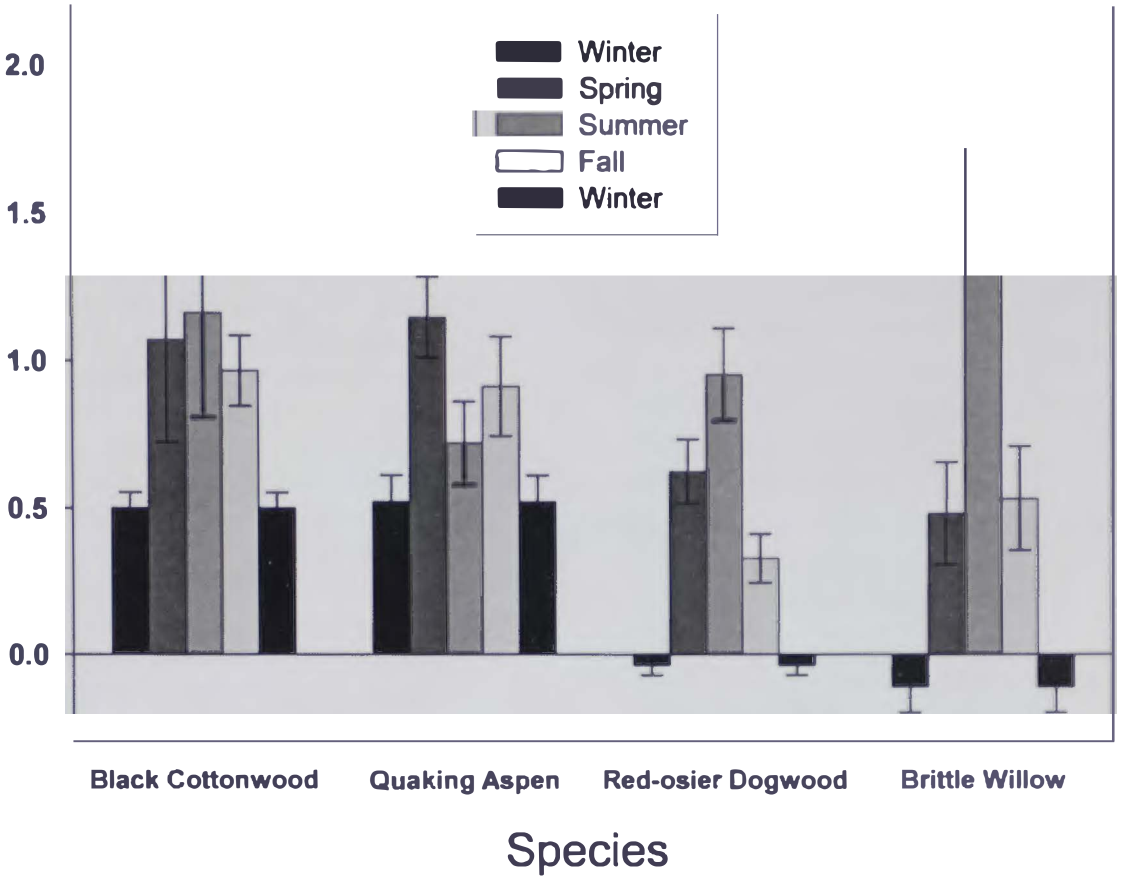

Figure 1. Gross photosynthesis (CO_2 evolution$_{dark}$ - CO_2 evolution$_{light}$) for each species during the four seasons. The second winter bar in each series is a repeat of the first winter bar made to emphasize the annual cycle of photosynthetic activity. Means with the same letter are not significantly different at α = 0.05 within each species. Data are means ± 1 SEM ($n = 6$).

photo-protective compounds anthocyanins (red) and carotenoids (yellow, Steyn et al. 2002). Increasing chlorophyll concentrations commonly observed in many woody tree species might explain simultaneous, but lesser, brightening of aspen and cottonwood stems in spring (Berveiller et al. 2007), including aspen (Foote and Schaedle 1976).

Production

In our experiments, cross-bark photosynthetic potential is generally proportional to respiration potential, suggesting a possible parallel response to environmental conditions, e.g., temperature or drought. Our 90-percent cross-bark fixation rates are within the range of 31 to 126 percent fixation observed by others (reviewed in Teskey et al. 2008). With the exception of our winter observations of dogwood and willow, the mean fixation rate observed in our work is very near that observed in the studies of Foote and Schaedle 1976, Han and Suzaki 1981, Wittmann et al. 2001, Wittmann et al. 2006, and Berveiller et al. 2007.

We hypothesize that the benefits of stem photosynthesis exceed those measured at the twig surface due to metabolic activity occurring in tissues too deep to readily exchange CO_2/O_2 with the external atmosphere. At this depth, photosynthesis fuels two processes. First, in a short (isolated) segment of the stem, photosynthesis and respiration continually cycle CO_2/O_2 as a source of energy (ATP). In this role the photosynthate cannot be withdrawn as a substrate for synthesis without interrupting (or breaking) the cycle. As an energy source this process is more efficient than leaf photosynthesis because the high internal CO_2 concentration of stems increases production both by mass

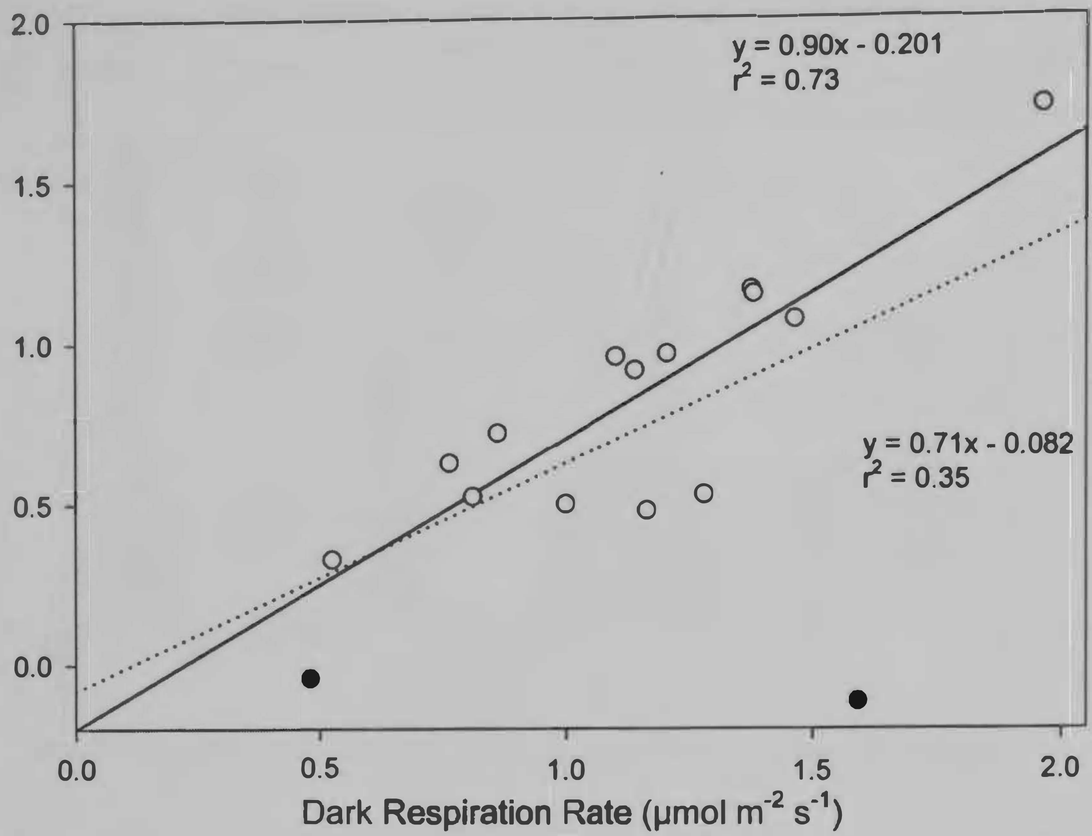

Figure 2. The relationship of mean gross photosynthesis (CO_2 evolution$_{dark}$ - CO_2 evolution$_{light}$) to dark respiration rate for all species during all seasons (r^2 = 0.37, dashed line). And for all species and seasons when anomalous winter data for dogwood and willow (closed circles) were removed (r^2 = 0.73, solid line) n = 6 for each data point.

action and reducing photorespiration (Aschan and Pfanz 2003, Tesky et al. 2008). Simultaneously, photosynthesis occurring without exchange with the outer atmosphere was more water-use efficient than surficial photosynthesis because it does not involve water losses associated with leaf photosynthesis. Second, internal photosynthesis incorporated for growth concentrated CO_2 rising from respiration in the stem, roots and soil (Billings and Godfrey 1967, Teskey et al. 2008). Because the source is continual, resultant sugars can be used either as a substrate for wood production or to fuel production or phloem activity. Because metabolic processes are generally reduced by cooling, we expect the effects of seasonal warming and cooling on internal photosynthesis to parallel those of external photosynthesis and respiration.

Seasonality

The winter observations of red-osier dogwood and brittle willow provide the first examples of complete winter cessation (or 'down-regulation') of stem photosynthesis. In contrast, our tree species maintained positive winter photosynthetic rates (aspen 50% and cottonwood 63%). Similarly, only partial winter down-regulation of photosynthetic capacity (34-90%) has been observed in six tree species (Damesin 2003, Berveiller et al. 2007).

Why has winter-time down-regulation, apparently absent in trees, evolved in typically shrubby genera (dogwood and willow). We offer two hypotheses. First, the difference could be due to random (non-selective) fixation of a winter down-regulation of photosynthesis in the two shrubby genera. If so, it seems somewhat odd that both of the shrub genera tested shut down while this phenomenon has not been observed in any tree species studied. The significance of this difference could be tested by comparing established tree behavior with a larger sample of shrubs. Alternatively, the winter-time down-regulation of photosynthesis in shrubby genera may have been under greater selective pressure than in trees. That is, because low shrubs are more subject to browsing than are taller trees, one might expect the twigs of shrubs to be more strongly selected for low palatability, i.e., low sugar and/or high toxin contents. Under this scenario, twig photosynthesis of shrubs might be down-regulated in winter to reduce the contents of palatable sugars in the browsing season, and up-regulated again in the spring when stem photosynthesis is needed (to support bud growth and recover carbon lost through increasing stem respiration) and browsing is reduced (due to the appearance of alternative forage). Circumstantial evidence for this hypothesis might be found by comparing the winter and summer contents of twigs with respect to presumed attractants, e.g., sugars, and repellents, e.g., phenolics.

CONCLUSIONS

The potential photosynthetic and respiratory capacities of four hardwoods, red-osier dogwood, brittle willow, quaking aspen and black cottonwood, were measured across the four seasons. Respiration in all four species occurred in all seasons, usually rising from winter to summer and falling again to winter. On average, measured carbon fixation compensated for 90 percent of stem respiration. Unmeasured internal photosynthesis is hypothesized to add to cross-bark photosynthesis, probably resulting in positive total photosynthesis. All species photosynthesized during spring, summer and fall, but in winter potential photosynthesis was reduced in aspen and cottonwood and completely down-regulated in dogwood and willow. To explain the unusual cessation of photosynthesis during winter in dogwood and willow, we offer alternate hypotheses regarding random non-selected vs. browsing selected evolution.

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LITERATURE CITED

Aschan, G. and H. Pfanz. 2003. Non-foliar photosynthesis–a strategy of additional carbon acquisition. Flora 198:81-97.

Berveiller, D., D. Kierzkowski, and C. Damesin. 2007. Interspecific variability of stem photosynthesis among tree species. Tree Physiology 27:53-61.

Billings, W. and P. Godfrey. 1967. Photosynthetic utilization of CO by hollow-stemmed plants. Science 158:121-123.

Box, G. E. P., W. G. Hunter. and J S. Hunter. 1978. Statistics for experimenters. John Wiley and Sons, Inc., New York, NY. 653 pp.

Cernusak L. A., Marshall J. D. 2000. Photosynthetic refixation in branches of Western white pine. Functional Ecology 14:300–311.

Comstock J. P., T. A. Cooper, and J. R. Ehleringer. 1988. Seasonal patterns of canopy development and carbon gain in 19 warm desert shrub species. Oecologia 75:327–335.

Damesin, C. 2003. Respiration and photosynthesis characteristics of current-year stems of *Fagus sylvatica*: from the seasonal pattern to an annual balance. New Phytologist 158:465-475.

Foote, K. and M. Schaedle 1976. Physiological characteristics of photosynthesis and respiration in stems of *Populus tremuloides* Michx. Plant Physiology 58:91-94.

Han S. S. and T. Suzaki. 1981. Studies on the production and consumption of assimilates by trees. IX. Bark photosynthesis and dark respiration of young green stems and branches of *Fagus crenata* and *Quercus acutissima*. Journal of the Japanese Forestry Society 63:242–244.

Huber, B. 1956. Die transpiration von Sprossachsen and andern nicht foliosen Organen. Pp. 427-435 *in* H Ruhland 1956. Encyclopedia of Plant physiology, Vol III, water relations of plants. Sringer-Verlag, Berlin, Germany 1073 pp.

Kharouk V. I., E. M. Middleton, S. L. Spencer, B. N. Rock, and D. L. Williams. 1995. Aspen bark photosynthesis and its significance to remote-sensing and carbon budget estimates. in the boreal ecosystem. Water Air and Soil Pollution 82:483–497.

Kyte, C. R. 1975. An autecological study of *Vaccinium scoparium*. MS thesis, University of Wyoming, Laramie.

Larcher, W. 1995. Physiological plant ecology. Springer, New York, NY. 506 pp.

Pfanz, H. and G. Aschan. 2001. The existence of bark and stem photosynthesis and its significance for the overall carbon gain. An eco-physiological and ecological approach. Progressive Botany 62:477–510.

Pfanz, H., G. Aschan, R. Langenfeld-Heyser, C. Wittmann, and M. Loose. 2002. Ecology and ecophysiology of tree stems: corticular and wood photosynthesis. Naturwissenschaften 89:147-162.

Steyn, W. J., S. J. Wand, D.M. Holcroft, and G. Jacobs. 2002. Anthocyanins in vegetative tissues: a proposed unified function in photoprotection. New Phytologist 155:349–361

Teskey, R. O., A. Saveyn, K. Steppe, and M. A. McGuire. 2008. Origin, fate and significance of CO_2 in tree stems. New Phytologist 177:17-32.

Wittmann C, Aschan G, Pfanz H. 2001. Leaf and twig photosynthesis of young beech (*Fagus sylvatica*) and aspen (*Populus tremula*) trees grown under different light regime. Basic and Applied Ecology 2: 145–154.

Wittmann C, Pfanz H, Loreto F, Centritto M, Pietrini F, Alessio G. 2006. Stem CO_2 release under illumination: Corticular photosynthesis, photorespiration or inhibition of mitochondrial respiration? Plant, Cell and Environment 29:1149–115.

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AN EXPERIMENTAL TEST OF FACTORS ATTRACTING DEER MICE INTO BUILDINGS

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ABSTRACT

Deer mice (*Peromyscus maniculatus*) are the principal reservoir host of Sin Nombre virus (SNV). Deer mice use a wide variety of habitats including peridomestic settings in and around human dwellings, their presence in and around homes has been implicated as a risk factor for acquiring Hantavirus Pulmonary Syndrome. Deer mice are believed to enter buildings in order to gain access to a variety of resources including food, bedding material, and better thermal microclimates. However, no one has experimentally tested which factors influence mice use of buildings. We conducted experiments using small simulated buildings to determine the effects of two factors, i.e., food and bedding material, on mouse activity in these buildings. We also examined if these effects varied with time of year. We found that deer mice entered our buildings regardless of the presence or absence of food or bedding. However, the amount of activity in buildings was affected by what they contained. We found significantly higher indices of activity in buildings containing food compared to both empty buildings (control) and buildings containing bedding material. Time of year did not affect activity in buildings .

Key words: deer mice, hantavirus, Montana, *Peromyscus maniculatus*

INTRODUCTION

Deer mice (*Peromyscus maniculatus*) are the principal reservoir host of Sin Nombre virus (SNV), the etiologic agent of hantavirus pulmonary syndrome (HPS), which was initially described in the southwestern United States (Childs et al. 1994; Nichol et al. 1993). Deer mice are also one of the most widely distributed mammals in North America (Baker 1968). They occur in a wide variety of natural habitats but they are also known to enter human dwellings in both rural (Glass et al. 1997) and urban areas (Kuenzi et al. 2000). Deer mouse presence in and around homes has been implicated as a risk factor for acquiring HPS (Armstrong et al. 1995).

Speculation holds that mice enter buildings to gain access to a variety of resources including food, bedding material, and better thermal microclimates. Whereas several studies have evaluated methods to exclude rodents from human dwellings (Glass et al. 1997, Hopkins et al. 2002), no experimental tests have been completed pertaining to what factors influence mice use of buildings. To design public health measures intended to avoid or decrease human exposure to hantaviruses, information on what factors attract mice into buildings is needed. The purpose of this study was to determine the effects of two factors, i.e., food and bedding material, on mouse activity in buildings and if these effects varied with time of year or surrounding habitat.

METHODS

This study was conducted near Gregson, Silver Bow County, Montana, from August 1998 through July 1999. Data from a previous study (Kuenzi et al. 2001) indicated that deer mice were the most common small mammal in the area and that these mice frequently lived in and entered outbuildings within the study site.

To determine what factors attract mice to buildings, we established two sets of three experimental buildings. These experimental buildings were designed to simulate typical outbuildings, such as sheds, that may attract mice. Buildings were small

4 x 8 x 4-ft structures made of wood with 3.8-cm (1.5-in) diameter circular openings in each of the four corners. A 23 X 11 grid of 10.6 X 10.6-cm (4.17 X 4.17-in) squares was permanently drawn on the floor of each building, for a total of 253 squares. We placed one set of buildings in a pasture lightly grazed by cattle hereafter referred to as grazed pasture and the other set in ungrazed bitterbrush (*Purshia tridentada*) and sage (*Artemesia* spp.). Individual buildings in each set of buildings were placed in a row with ~ 20-m spacing between buildings.

We monitored mouse activity in the buildings for 9 consecutive nights during each experimental trial. At the start of each trial, we randomly assigned three different treatments to each of the three buildings within each set. Treatments included food (a mixture of oatmeal and peanut butter), bedding material (cotton batting), and control (nothing added to the building). Food and bedding treatments were placed in the middle of the buildings. Buildings were opened in the evening and small petri dishes of fluorescent powder (Radiant Color, Richmond, California) were placed at openings in the corners of each building. Buildings were checked each morning for presence of mouse tracks using a black light. As mentioned previously, the floor of each building was marked with a 23 X 11 grid of 10.6 X 10.6-cm (4.17 X 4.17 in) squares for a total of 253 squares. We used the number of grid squares containing mouse tracks as our index of mouse activity. Floors were then cleaned using a mixture of viral disinfectant and water. Buildings were closed during the daytime to limit access by diurnal rodents, e.g., chipmunks and voles.

We monitored mouse activity for 3 nights before reassigning each treatment to a different building. By the end of the 9-night experimental trial, each building had received all three treatments. We classified each trial as falling into one of the four seasons (spring, summer, fall and winter) depending upon dates during which the trial was conducted. We used standard dates for determining season (Spring = 21 Mar - 20 Jun, Summer = 21 Jun - 20 Sep, Fall = 21 Sep - 20 Dec, and winter = 21 Dec - 20 Mar). For each building in the study, we calculated a seasonal average of activity for each treatment condition.

Data were analyzed using a two-way (Season X Treatment) repeated measures ANOVA with repeated measures on both factors. Buildings were treated as our subjects and the dependent measure was mouse activity level within a building. Data were analyzed from the grazed pasture and bitterbrush/sage habitats separately. Because there were statistical concerns regarding the sphericity assumption underlying the use of our repeated measures analyses, all repeated measures ANOVA statistical results were reported using the Greenhouse-Geisser adjustment (Maxwell and Delaney 1990). Statistical analyses were done with the SPSS v11.0 (SPSS Inc., Chicago, IL).

RESULTS

We conducted 22 experimental trials during the course of this study; 16 of these trials were conducted in the experimental buildings located in the grazed pasture and six trials were conducted in the buildings located in the bitterbrush/sage habitat. The number of trials conducted during each season varied due to logistical constraints. In the pasture habitat, we conducted six trials during summer, five during fall, two during winter, and three during spring (Table 1). In the bitterbrush/sage habitat we conducted two trials during fall, winter and spring but no trials during summer (Table 2). Mean activity varied by season and treatment for both the buildings in the pasture habitat (Table 1) and those in the bitterbrush/sage habitat (Table 2).

In buildings located in the bitterbrush/sage habitat we detected no significant Season X Treatment effect (Table 3) indicating that the effect of treatments (food, bedding, control) on mean activity level was the same across seasons. We also detected no statistically significant season effect on mean activity levels in both habitats indicating that activity levels were similar among seasons. However, there

Table 1. Average index of mouse activity in buildings located in the pasture habitat by season, Silver Bow County Montana, August 1998- July 1999.

	Spring (3 trials)			Summer (6 trials)			Fall (5 trials)			Winter (2 trials)		
Building	**Food**	**Bedding**	**Control**	**Food**	**Bedding**	**Control**	**Food**	**Bedding**	**Control**	**Food**	**Bedding**	**C**
1	71.1	51.4	58.4	213.3	98.0	73.0	181.3	64.9	77.2	83.0	37.8	52.8
2	184.2	50.9	31.6	119.5	56.5	87.0	152.7	67.7	43.7	112.2	50.5	40.7
3	149.6	147.6	44.4	204.8	75.2	75.0	128.9	91.3	69.9	130.7	10.3	30.0
Average	134.9	83.3	44.8	179.2	76.5	78.3	154.3	74.6	63.6	108.6	32.8	41.2
St. Dev	57.9	55.7	13.4	51.9	20.8	7.6	26.2	14.5	17.6	24.0	20.5	11.3

Table 2. Average index of mouse activity in buildings located in the bitterbrush-sage habitat by season, Silver Bow County Montana, August 1998- July 1999.

	Spring (3 trials)			Fall (2 trials)			Winter (2 trials)		
Building	**Food**	**Bedding**	**Control**	**Food**	**Bedding**	**Control**	**Food**	**Bedding**	**Control**
1	188.2	64.2	52.5	218.5	12.3	41.8	125.5	45.5	43.2
2	215.2	39.2	84.0	84.5	80.3	33.8	121.2	36 8	32.0
3	198.8	60.3	76.2	130.3	58.2	7.7	110.8	24.2	36.0
Average	200.7	54.5	70.9	144.4	50.3	27.8	119.2	35.5	35.1
St. Dev	13.6	13.4	16.4	68.1	34.7	17.8	7 5	10 7	5.7

was a significant treatment effect (Table 3). The mean activity level in buildings containing food (Mean = 154.8, SE = 11.5) was statistically higher than mean mouse activity levels in control buildings (Mean = 45.2, SE = 2.9) or buildings that contained bedding (Mean = 46.8, SE = 3.3). Activity in control buildings versus those that contained bedding did not differ from one another.

We obtained similar results for the buildings located in the grazed pasture habitat. We detected neither a significant Season X Treatment effect nor a significant Season effect (Table 3). There was a significant Treatment effect. Similar to buildings in the bitterbrush/sage habitat, mean activity level in buildings in the grazed pasture containing food (Mean = 144.3, SE = 4.8) was statistically higher than mean mouse activity levels in control buildings (Mean = 56.9, SE = 4.4) or buildings that contained bedding (Mean = 66.8, SE= 7.4). Activity in control buildings versus those that contained bedding did not differ from one another.

DISCUSSION

A common belief holds that mice enter buildings to gain access to food. However, in a study of rodent exclusion techniques, Glass et al. (1997) demonstrated that *Peromyscus* spp. invaded rural housing that had not been rodent proofed but in which all food had been removed. We also found that deer mice entered buildings regardless of the presence or absence of food. During all seasons, and in both ungrazed pasture and bitterbrush/sage habitats, we documented some deer mice activity in all experimental buildings. However, the amount of activity in buildings was affected by what they contained. We found significantly higher indices of activity in buildings containing food compared to both empty buildings (control) and buildings containing bedding material. This pattern was consistent in both the grazed pasture and the bitterbrush/sage habitats. Thus, buildings that contain accessible food resources are likely to be used for longer periods of time and possibly by more individuals than buildings without food.

We detected no statistically significant seasonal differences in activity levels in buildings across seasons in either of the two habitats examined. Intuitively it makes sense that more mice might enter buildings in the fall to gain access to the better thermal microclimate afforded by housing. Our experimental buildings were not heated and were structurally very simple, so our lack of seasonal differences may be due to our buildings not providing microclimates any different than outside. However, other studies have documented mouse presence in homes throughout the year. Glass et al. (1997) captured mice inside National Park Service dwellings during all seasons and Kuenzi et al. (2000) captured mice inside of homes in Montana throughout the year except during January. Thus, mice appear to enter buildings opportunistically.

Our results indicate the importance of rodent-proofing homes to protect humans from exposure to SNV. Recommendations on how to rodent proof homes are available (Centers for Disease Control and Prevention 2002) and effectiveness of several different rodent exclusion methods has been evaluated (Glass et al. 1997, Hopkins et al. 2002). In buildings that are impossible to rodent proof, our results indicate the importance of eliminating rodent access to food resources and taking

Table 3. Results from the two-way (Season X Treatment) repeated measures ANOVA assessing the effects of building treatment and season on mouse activity.

	Grazed Pasture			Bitterbrush/sage		
	df	F	P	df	F	P
Season	3,1.6	3.67	0.151	2, 1.05	14.95	0.057
Treatment	2, 1.4	88.8	0.003	2, 1.05	63.3	0.013
Season * Treatment	6, 1.9	0.417	0.677	4, 1.10	0.849	0.460

personal precautions to avoid contact with contaminated (by mouse urine and feces) dust or other particulate matter.

ACKNOWLEDGMENTS

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LITERATURE CITED

Armstrong, L. R., S. R. Zaki, M. J. Goldoft, R. L. Todd, A. S. Khan, R. F. Khabbaz, T. G. Ksiazek, and C. J. Peters. 1995. Hantavirus pulmonary syndrome associated with entering or cleaning rarely used, rodent-infested structures. Journal of Infectious Diseases 172:1166-1166.

Centers for Disease Control and Prevention. 2002. Hantavirus pulmonary syndrome—United States: updated recommendations for risk reduction. MMWR 2002;51 (No. RR-9).

Childs, J. E., T. G. Ksiazek, C. F. Spiropoulou, J. W. Krebs, S. Morzunov, G. O. Maupin, K. L. Gage, P. E. Rollin, J. Sarisky, R. E. Enscore, J. K. Frey, C. J. Peters, and S. T. Nichol. 1994. Serologic and genetic identification of *Peromyscus maniculatus* as the primary rodent reservoir for a new hantavirus in the southwestern United States. Journal of Infectious Diseases 169:1271-1280.

Glass, G. E., J. S. Johnson, G. A. Hodenbach, C. L. J. Disalvo, C. J. Peters, J. E. Childs, and J. N. Mills. 1997. Experimental evaluation of rodent exclusion methods to reduce hantavirus transmission to humans in rural housing. American Journal of Tropical Medicine and Hygiene 56:359-364.

Hopkins, A. S., J. Whitetail-Eagle, A. L. Corneli, B. Person, P. J. Ettestad, M. Dimenna, J. Norstog, J. Creswell, A. S. Khan, J. G. Olson, K. F. Cavallaro, R. T. Bryan, J. E. Cheek, B. Begay, G. A. Hoddenbach, T. G. Ksiazek, and J. N. Mills. 2002. Experimental evaluation of rodent exclusion methods to reduce Hantavirus transmission to residents in Native American community in New Mexico. Vector Borne and Zoonotic Diseases 2:61-68.

Kuenzi, A. J., R. J. Douglass, and C. W. Bond. 2000. Sin Nombre virus in deer mice captured inside homes, southwestern Montana. Emerging Infectious Diseases 6:386-388.

Kuenzi, A. J., R. J. Douglass, D. White, C. W. Bond, and J. N. Mills. 2001. Antibody to Sin Nombre virus in rodents associated with peridomestic habitats in west central Montana. American Journal of Tropical Medicine and Hygiene 64:137-146.

Maxwell, S. E., and H. D. Delaney. 1990. Designing experiments and analyzing data: a model comparison perspective, Wadsworth, Belmont, CA.

Nichol, S. T., C. F. Spiropoulou, S. Morzunov, P. E. Rollin, T. G. Ksiazek, H. Feldmann, A. Sanchez, J. Childs, S. Zaki, and C. J. Peters. 1993. Genetic identification of a hantavirus associated with an outbreak of acute respiratory illness. Science 262:914-917.

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GUIDELINES FOR MANUSCRIPTS SUBMITTED TO THE INTERMOUNTAIN JOURNAL OF SCIENCES

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ABSTRACT

The staff and editorial board of the *Intermountain Journal of Sciences* (*IJS*) provide guidelines for authors who wish to submit manuscripts for publication. Manuscripts should follow the format and style presented here to assure prompt review and publication. Organization of manuscripts will vary somewhat to accommodate the content of the article.

Key words: author, format, guidelines, *Intermountain Journal of Sciences*, manuscript style.

INTRODUCTION

The *Intermountain Journal of Sciences* and its sponsoring organizations[1] encourage scientists, practitioners, educators, and students to submit their research, application, or viewpoints for consideration in *IJS*. This article provides authors with guidelines, using examples of style and format, for preparation of manuscripts and serves as an update to the style guidelines for *IJS* published earlier (Dusek 1995).

The general format of articles appearing in *IJS* has been approved by the editorial board. Organization may vary to accommodate content of the article; e.g., research, application, and opinion. This update also includes changes adopted by the editorial board in December 2000 that became effective with Volume 7 (2001).

The editorial board and staff intend these guidelines to provide authors with timely review and publication of their manuscripts. Manuscripts that deviate significantly from the approved style and format will be returned to the author(s) for corrections prior to being sent out for peer review.

POLICY

Scope

IJS and its sponsoring organizations offer an opportunity to publish papers presented at annual meetings of the respective organizations and have replaced printed proceedings through publication of *IJS*. Although manuscripts from papers presented at these meetings would receive publication priority if space were limited, the editorial board also encourages nonmembers to submit manuscripts for consideration in *IJS*.

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The editorial board approves page charges, which cover the cost of publication, and are adjusted as the cost of layout and printing change. Page charges for published manuscripts are currently $60/printed page and are assessed upon acceptance of

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[1] Sponsoring organizations include the Montana Academy of Sciences and Montana Chapters of the American Fisheries Society and the Wildlife Society.

manuscripts for publication. Page charges to sponsoring organiztions for printing abstracts from annual meetings are currently $40/printed page. Costs associated with significant alteration to page proofs, except for errors in the layout, will also be assessed to authors. Unless it is in the public domain, copyright is retained by the author(s).

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The date of submission (update with each revision), senior author's name, mailing address, and daytime phone number appear single-spaced in the upper left corner above the title on page 1. All text that follows should be double spaced.

The title should be centered, Title Format, and brief — preferably no more than ten words. Please avoid the use of scientific (Latin) names in the title.

Author and organization should be flush left, separated with commas, and a new line for each author. Authors should include first name, middle initial and last name. If needed, a second line should be indented five spaces (hanging indentation). Include the postal code in the author's address. The authors' address should reflect their affiliation at the time the work was done; if the address has changed by the time of publication, the current address should appear in a footnote on the title page (page 1).

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Headings other than the title are appropriate whenever length of the manuscript exceeds three double-spaced pages or whenever the text conveys two or more major ideas. Three levels of headings should be sufficient. First-level headings include all upper-case letters, are flush left, and may include bold face type. Second-level headings are flush left with only the first letter of each word capitalized. The second-level heading may also be in bold face type. Please indent third-level headings at the beginning of paragraph with the first letter of each word capitalized; the heading should be underlined followed by a period and two hyphens. Text follows the *run-in heading*.

Organization

Manuscripts dealing with original research are expected to include the following major headings: abstract, introduction, study area when applicable, methods and materials, results, discussion, and conclusions, acknowledgments, and literature cited. Authors may combine a description of the study area with the methods and materials. In other articles, authors may follow the introduction with major headings that appropriately address their topic.

Abstract.—An abstract, located immediately below the author's name, should express precisely the key information presented in the manuscript in a short paragraph of approximately 250 words and not to exceed 10 percent of the length of the manuscript. Manuscripts of three or less pages do not require an abstract. Those submitting only abstracts from presentations at annual meetings of co-sponsor organizations should stay within the 250-word limit.

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Editorial style, including punctuation, generally follows Freeman and Bacon (1990). Authors submitting manuscripts dealing with the biological sciences may wish to consult the Council of Biology Editors' style manual (CBE Style Manual Comm. 1983).

We encourage authors to use a scientific/technical style in manuscript preparation. This often includes use of technical terms, phrases, and jargon (common terms used in an uncommon way). Authors should use these terms in a manner that is understood by their targeted readership. To communicate with a broad, interdisciplinary audience for example, authors should provide an informal definition when technical terms, phrases, or jargon are first used. This example should similarly apply to terms in which the context is limited to a single discipline, agency or small working group.

Remember that poor writing often contributes to unfavorable reviews and lengthy delays in publication of otherwise well-conceived manuscripts. Avoid sentences that are long and clumsy with pompous and abstract phrases (e.g., use "trees" instead of "residual timber resources" if they imply the same meaning). Use concise, direct sentences when practical using pronouns and active verbs (e.g., "We concluded...") rather than false subjects and passive verbs (e.g., "It was concluded...").

Well-conceived illustrations provide a powerful medium for communicating scientific results. The text should summarize and support the data in tables and figures and not repeat it.

Numbers and Measurements

Numbers are spelled out when they begin a sentence or are less than 10 and not accompanied by a unit of measurement.

The numerical form is always used for dates, expressions of time, page numbers, decimals, numerical designations, ratios, and for numbers greater than and including 10. For a very large, rounded number (e.g., 1 million), use a combination of numbers and letters. Always use numbers when expressing decimals or percentages. Spell out "percent" when used in text but use the symbol (%) when used in chemical formulas, tables, figures, or in parentheses. For *IJS* articles, dates should be written day-month-year without punctuation (e.g., 15 June 1995). Use the 24-hour system to express time (0001-2400 hours).

Use metric units of measurement. This system is preferred among the sciences and many areas of engineering. Although not required, authors may provide English equivalents. For example, "The study area encompassed 40 ha (100 ac)." Units should be abbreviated when following a number. Do not follow an abbreviated unit of measure with a period.

Mathematical and Statistical Terms

Italicize Roman letters used to symbolize quantities (e.g., n, t, x and P). Do not underline Greek letters or trigonometric functions. Displayed expressions (e.g., formulas) are separated from the text — centered with two spaces above and below.

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References should be mentioned in the text in a manner such as Seward and Davis (1990), or embedded in text (Daubenmire 1968, Hess 1986, Lyon and Canfield 1991). When listed in sequence within text, authors should be listed in order of year of publication. In the Literature Cited section, all references should be listed in alphabetical order by the first author's last name. If citing the same author for more than one reference, cite in order of publication year. If co-authors differ among several citations of the same senior author, list those references with the author's last names, initials for given names. Please refer to the following examples.

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Refereed Journal Article

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Footnotes, other than those in tables, are used in *IJS* for two purposes: 1) to denote a change in an author's address, agency affiliation, or deceased author; and 2) to denote that the article is the published manuscript of a presentation given at an annual meeting of one of the co-publishers. These footnotes appear at the bottom of the title page and should be numbered consecutively.

We allow use of appendices if essential to the paper. They should be labeled Appendix A, Appendix B, etc. Appendices usually contain background information, tables of detailed results, and lengthy analyses. They are appropriate if a knowledgeable reader would need the information to interpret the conclusions.

TABLES, GRAPHS AND IMAGES

Tables

Each table must be mentioned in the text and numbered consecutively with Arabic numerals. When embedded in text of a sentence or embedded in parentheses, "Table 1" is written out. Tabular material should stand alone and not be repeated within the text. Footnotes to tables start with "1" for each table and are separate from text footnotes.

Do not insert tables within the text of the manuscript. Rather, arrange them consecutively at the end of the manuscript and preferably with no more than one table per page. All tables should be double-spaced and in appropriate table format that includes table number and caption, column headings (boxhead), body, and footnote . Use tabs not spaces is setting up your columns. A sourceline should follow the footnotes in cases where information is from a source other than the author.

Keep tables as simple as possible with columns of data clearly separated. Do not use vertical lines in tables. Tables may continue beyond a single page, but continuation headings should appear on subsequent pages. We prefer tables to be constructed for column-width printing (67 mm), but we will accommodate those for page-width printing (138 mm) and if the table is larger than page width, we may have to landscape it in the publication.

Table 5. Temporal Distribution of the *S. arcticum* IIL-10 Cytospecies at Upper Spring Creek, Fergus County, Montana.

Date	Females X_0 X_0	Males X_0 Y_{10}
1/22/05	4	11
1/26/03	11	25
2/7/04	3	2
2/17/02	3	1
2/27/04	12	8
3/25/06	5	10
4/24/04	37	25
5/21/05	8	1
7/16/05	1	6
10/5/03	9	3
Total	102	92

Figures

All figures should be mentioned in the text. When embedded in text of a sentence, "Figure 2" is written out. If enclosed in parentheses, abbreviate reference to the figure (Fig. 2). Line drawings and photos can be submitted of any reasonable size.

Table 1. The 24-hr and 96-hr LC50 values (± 95% CI) for Columbia spotted frogs, long-toed salamanders and tailed frogs exposed to Fintrol and Prenfish.

		Fintrol (µg/L)		**Prenfish (mg/L)**	
species	**life stage**	**24 hr**	**96 hr**	**24 hr**	**96 hr**
Columbia spotted frog	Adult	>250 a (---)	192 (141-313)	41.5 (33.9-50.9)	9.65 (7.8-12.0)
Long toed salamander	Adult	Av	b	8.0 (6.6-9.8)	3.5 (0.8-4.9)
	Larvae	225 (150-300)	81.7 (66.8-99.1)	<0.23 c (---)	<0.23 d (---)
Tailed frog	Larvae	77.6 (66.3-90.7)	13.7 (11.1-16.7)	0.037 (0.030-0.047)	0.009 (0.007-0.012)

a – no effect at greatest exposure (250) within 24 hr

b – exposed to 7.5 µg/L for 96 hr with no mortality

c – lowest level (0.23) caused 70 percent mortality at 24 hr

d – lowest level caused 100 percent mortality at 72 hr

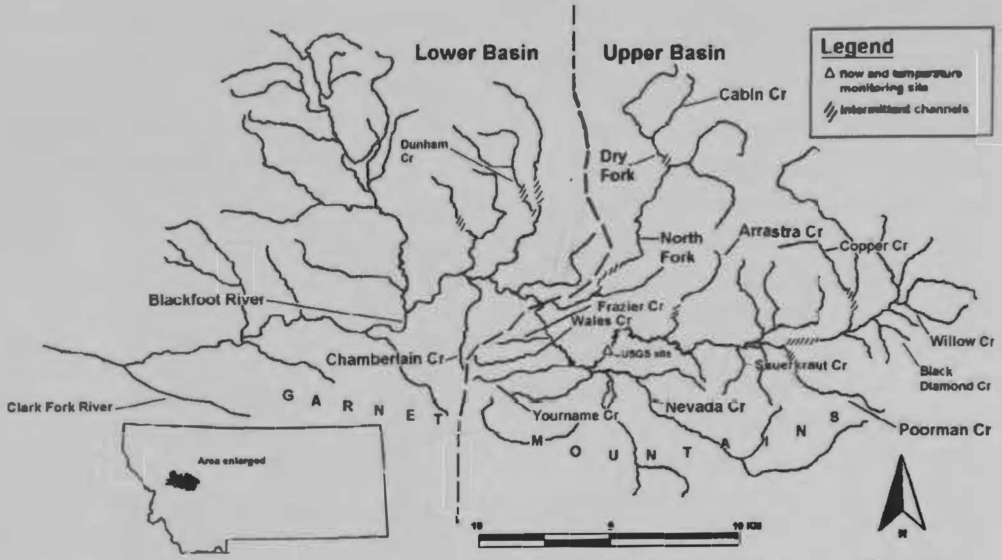

Figure 1. Study area: upper Blackfoot River basin with water temperature and flow monitoring station and intermittent stream channels

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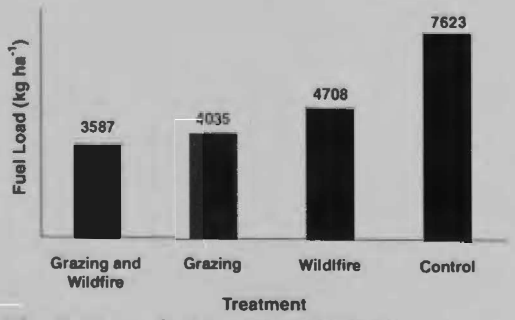

Fig. 2. Mean fuel load (kg ha-1) by treatment type. Fuel load estimations are from field observations.

All figures should be submitted in digital format as high resolution files (300 dpi). Please save the figures separately and do not insert them into the word document. We can accept high resolution jpg, tif, eps and pdf files. If you cannot provide these types of files please contact us to make other arrangements.

ACKNOWLEDGMENT

I extend special thanks to J. P. Weigand for his contributions to development of *IJS* style guidelines. I also appreciate the encouragement, support, and helpful comments of R. J. Douglass, T. N. Lonner, and A. V. Zale. Funding for this project was provided by *IJS*.

LITERATURE CITED

CBE Style Manual Committee. 1983. CBE style manual. Fifth Ed. Council of Biology Editors, Bethesda, MD. 324 pp.

Freeman, L. H., and T. R. Bacon. 1990. Shipley Associates style guide. Rev. ed., Shipley and Associates, Bountiful, UT.

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