Responses of riparian and stream ecosystems to varying timing and intensity of livestock grazing in central Montana

by Carol Leigh Endicott

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Riparian vegetation plays a key role in maintaining fish populations in Rocky Mountain streams bordering rangelands. Excessive use of of riparian areas can lead to loss of riparian overstory, stream bank degradation, increased sedimentation, decrease of instream habitat quality, higher summer and lower winter water temperatures and reductions in fish populations. The objective of this study is to evaluate how riparian and stream ecosystems respond to varying duration, timing and intensity of livestock grazing on several ranches in central Montana, and to suggest the sustainability of each practice. Comparisons include: long-term livestock exclusion (> 20 years) and spring grazing; winter and summer grazing; and short-term exclusion (5 years) and continuous, season-long grazing.

Results indicate differences between long-term exclusion and spring grazing with greater density of key palatable woody species (willow and dogwood); better bank conditions; higher fish habitat quality; and greater trout density under conditions of livestock exclusion. Functional feeding group composition and productivity of benthos differed among conditions of livestock exclusion and spring-grazed sections.

Comparisons of winter-grazed and summer-grazed treatments show greater density of palatable species in the summer-grazed section and increased browse utilization in the winter-grazed section. The summer-grazed section showed better habitat conditions for trout, primarily in the form of high quality pool habitat with abundant woody debris. A corresponding greater density of brook trout was found in the summer-grazed section. Benthic communities were not influenced by grazing strategy. Comparisons of short-term exclusion with pre-fencing photographs and the continuously grazed section indicate marked recovery of riparian communities and bank conditions in this section. The fenced section also showed greater ability to retain organic matter. Despite recovery of habitat conditions, salmonid populations have shown no improvement. This is likely due to upstream perturbations which include extensive riparian degradation and a flood control impoundment. Communities of benthic macroinvertebrates were shaped more by these upstream perturbations than by grazing treatment. Comparison of numbers and biomass of terrestrial invertebrates in surface drift did not show differences among fenced or continously grazed sections.

Management implications based on these results indicate that sustainable practices are those that maintain the functional attributes of riparian communities. Riparian areas should be considered as separate management units, distinct from upland communities. Sustainable grazing strategies should be determined on a site-specific basis given the variability of response due to differences in riparian community type, landform, and weather patterns.

RESPONSES OF RIPARIAN AND STREAM ECOSYSTEMS TO VARYING TIMING AND INTENSITY OF LIVESTOCK GRAZING IN CENTRAL MONTANA

by

Carol Leigh Endicott

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY-BOZEMAN
Bozeman, Montana

January 1996

APPROVAL

of a thesis submitted by

Carol Leigh Endicott

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Thomas E. McMahon — Thomas E. McMahon (Signature) — 20 February 1996 Date

Approved for the Department of Biology

Ernest R. Vyse — E R Vyse (Signature) — February 20, 1996 Date

Approved for the College of Graduate Studies

Robert L. Brown — R L Brown (Signature) — 4/1/96 Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University-Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission extended quotation from or reproduction of this thesis in while or in parts may be granted only by the copyright holder.

Signature Carol Endicott

Date February 20, 1996

ACKNOWLEDGEMENTS

I'd like to thank a number of organizations and individuals who contributed to this study. Sustainable Agriculture Research and Education (SARE) provided the funding. The Gatz, Swanz and Comes families permitted me access to their property and furnished valuable information. Dave Phillips and the Fergus County Extension Service provided a variety of logistical support. The Big Spring hatchery contributed space and other resources.

A number of volunteers and technicians assisted in the field and with lab work. I'd like to thank Jennifer Staples, Mindy Meade, Mike Miller, Scott Barndt, Adam McMahon, Sue Ireland, and Mark Koebbe. Robert Bramblett volunteered numerous valuable weekends to assist with field work. Thanks to Dan Gustafson for assistance with identification of benthic macroinvertebrates.

Thanks to my major professor, Thomas E. McMahon for support and guidance throughout this process. I'd like to thank my committee members, Robert G. White, Jay Rotella and Clayton Marlow for support in completion of this thesis. Robynn Tierney also provided information and support.

TABLE OF CONTENTS

TABLE OF CONTENTS, Continued

LIST OF TABLES

LIST OF TABLES, Continued

LIST OF TABLES, Continued

LIST OF FIGURES

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

ABSTRACT

Riparian vegetation plays a key role in maintaining fish populations in Rocky Mountain streams bordering rangelands. Excessive use of of riparian areas can lead to loss of riparian overstory, stream bank degradation, increased sedimentation, decrease of instream habitat quality, higher summer and lower winter water temperatures and reductions in fish populations. The objective of this study is to evaluate how riparian and stream ecosystems respond to varying duration, timing and intensity of livestock grazing on several ranches in central Montana, and to suggest the sustainability of each practice. Comparisons include: long-term livestock exclusion (> 20 years) and spring grazing; winter and summer grazing; and short-term exclusion (5 years) and continuous, season-long grazing.

Results indicate differences between long-term exclusion and spring grazing with greater density of key palatable woody species (willow and dogwood); better bank conditions; higher fish habitat quality; and greater trout density under conditions of livestock exclusion. Functional feeding group composition and productivity of benthos differed among conditions of livestock exclusion and spring-grazed sections. Comparisons of winter-grazed and summer-grazed treatments show greater density of palatable species in the summer-grazed section and increased browse utilization in the winter-grazed section. The summer-grazed section showed better habitat conditions for trout, primarily in the form of high quality pool habitat with abundant woody debris. A corresponding greater density of brook trout was found in the summer-grazed section. Benthic communities were not influenced by grazing strategy. Comparisons of short-term exclusion with pre-fencing photographs and the continuously grazed section indicate marked recovery of riparian communities and bank conditions in this section. The fenced section also showed greater ability to retain organic matter. Despite recovery of habitat conditions, salmonid populations have shown no improvement. This is likely due to upstream perturbations which include extensive riparian degradation and a flood control impoundment. Communities of benthic macroinvertebrates were shaped more by these upstream perturbations than by grazing treatment. Comparison of numbers and biomass of terrestrial invertebrates in surface drift did not show differences among fenced or continously grazed sections.

Management implications based on these results indicate that sustainable practices are those that maintain the functional attributes of riparian communities. Riparian areas should be considered as separate management units, distinct from upland communities. Sustainable grazing strategies should be determined on a site-specific basis given the variability of response due to differences in riparian community type, landform, and weather patterns.

INTRODUCTION

Functions of Riparian Ecosystems

Riparian ecosystems consist of the plant and animal communities that border streams, rivers or other bodies of water and are often distinct from upland communities. These ecosystems are often more productive in terms of plant and animal biomass than upland areas and are a critical source of biological diversity within rangelands (Thomas et al. 1979). Functionally, riparian areas provide the link between terrestrial and aquatic ecosystems. Although riparian areas in the western United States constitute only a small proportion of land area, their importance with regard to fish, wildlife, and agriculture is enormous. Riparian areas and their associated lotic systems provide livestock with forage, shelter and water. Riparian vegetation, due to numerous functional attributes, is critical in supporting fish and wildlife communities and maintaining water quality.

A principal function of riparian vegetation is maintenance of bank stability (Platts and Nelson 1989a). Fine root systems bind soil particles and greatly increase resistance to soil erosion (Smith 1976). Trees and shrubs contribute structural support through their massive root systems which provide long-term bank stability (Beschta 1991). The above-ground portions of shrubs, grasses and forbs also confer bank stability. During flooding events, this vegetation forms protective mats over the banks, dissipating flow velocities and permitting the transported sediments to settle out thereby building banks and providing fertile soils (Platts and Rinne 1985). During winter months, vegetation promotes bank stability by insulating banks and reducing ice formation in the soil which reduces heaving and erosion (Bohn 1989).

Riparian vegetation also functions to influence the hydrological properties of the lotic system. Large woody debris (LWD) contributed from riparian stands serves to maintain channel stability and decrease bedload movement (Heede 1985). On a drainage level, ground cover is an important watershed characteristic because it functions to maintain high infiltration rates. This buffers stream discharge during flooding events and prevents soil erosion (Higgins et al. 1989).

A number of the functional attributes of riparian vegetation are associated with the maintenance of water quality. Riparian ecosystems serve as nutrient sinks and buffer nutrients and chemical discharge from surrounding agricultural areas (Lowrance et al. 1984). In addition, intact riparian zones function as crucial sites for nitrification processes (Lowrance et al. 1984; Green and Kauffman 1989). By limiting soil erosion, riparian vegetation reduces suspended solids during high flows. Riparian overstory shades the stream in the summer and limits heat loss in the winter, thereby reducing stream ice formation (Platts and Nelson 1989a).

Riparian vegetation plays a critical role in supporting instream biotic communities. In most headwater streams, macroinvertebrate communities depend on the allochthonous input of organic matter (leaves, twigs, etc.) from streamside vegetation (Cummins and Spengler 1978). Instream woody debris and exposed roots along the stream bank serve to detain and concentrate this organic matter so that it can be locally processed by aquatic insects (Cummins 1974; Smock et al. 1989).

Fish are largely dependent on the functional attributes of riparian vegetation to provide quality habitat. As mentioned earlier, stream morphology and stability are largely a function of streamside vegetation (Heede 1985; Platts and Nelson 1989b). Stream morphology and stability impact the hydrologic and hydraulic processes which in turn influence habitat for fish (Heede and Rinne 1990). Overhanging vegetation and undercut banks can be used as a measure of habitat suitability for salmonids (Contor and Platts 1991). Woody debris in the stream channel provides cover and rearing habitat which is particularly important in winter (Swales et al. 1986).

Riparian vegetation also influences fish populations as a source of terrestrial invertebrates for food. The importance of terrestrial invertebrates as a food source was reviewed by Hunt (1975) who found that terrestrial invertebrates constituted at least 50% of the diet of salmonids during one or more months in late summer and fall, and nearly 100% of daily forage during periods of "superabundance" of terrestrial species. The significance of increased availability of allochthonous sources of forage during certain periods may be considerable as these peaks of dependence on terrestrial invertebrates often coincide with a paucity of benthic sources (Hunt 1975).

Effects of Livestock Grazing on Riparian Ecosystems

Riparian areas of the United States have been subjected to extensive use. It has been estimated that only 2% of land in the United States is comprised of pristine riparian areas and that 70% of existing riparian ecosystems have been altered by human activities (Brinson et al. 1981). According to Kauffman and Krueger (1984), cattle prefer riparian areas because of water, thermal cover, shade and abundant succulent forage. As a result, grazing pressure on the riparian zone often exceeds that of upland areas and these habitats may sustain heavy impacts in the absence of effective management schemes.

One of the most obvious effects of livestock grazing on riparian areas are the changes in vegetation composition and structure. Grazing by livestock has been found to result in changes in plant succession and less ground cover compared to ungrazed areas (Leege et al. 1981). Excessive grazing by cattle has been found to decrease invasion sites for woody species (Kauffman 1988) and eliminate woody vegetation (Duff 1979).

Excessive vegetation removal and trampling by livestock disrupts the functions of riparian ecosystems as described above. One of the primary effects of this disruption is a reduction of bank stability and increased soil erosion. The degree of streambank degradation due to livestock grazing is related to several factors. Different stream types vary in bank degradation in response to grazing by livestock and the relative importance of vegetation in maintaining bank stability (Myers and Swanson 1992). Stream banks with non-cohesive gravel or sand dominated soils are most sensitive to livestock grazing.

These soil types are common in foothills and valleys which are frequently subjected to livestock grazing pressure.

Other factors involved in stream bank response to grazing by livestock are related to timing of grazing. In a study in southwest Montana of effects of grazing on stream bank stability, Marlow et al. (1987) reported that a combination of high flows, moist streambanks and cattle use led to major streambank alteration. Since the conditions of high flows and high soil moisture predominate in the spring, it was proposed that a generally applicable livestock grazing strategy would be to defer grazing until mid to late summer.

Another seasonally related factor of streambank response to grazing is related to soil temperature during winter. According to Platts (1989), winter grazing was considered to be effective in situations where the banks remain frozen. This author considered frozen stream banks to be more resistant to stress. This hypothesis, however, contradicts the suggestions make by Bohn (1989) who held that the formation of ice results in soils less able to withstand the stresses of trampling and high flows.

The degradation of riparian vegetation may change the hydrological properties of a watershed. Intensive grazing by livestock removes the protective vegetative mat resulting in a reduction of infiltration and an increase in storm runoff and erosion (Rauzi and Hanson 1966; Gifford and Hawkins 1978). In a study of watersheds subjected to differing grazing strategies, Higgins et al. (1989) reported that the watershed exposed to the highest intensity grazing had higher than average water yield, reduced infiltration, and more variable flows than less intensively grazed watersheds.

Other grazing-induced changes in the hydraulic properties of a stream are related to channel morphology. These changes are related to disruption of functional traits of woody vegetation as well as grasses and forbs. Bank degradation associated with loss of stream bank vegetation can result, over time, in the channel becoming wider and shallower (Platts 1979). Heede (1972; 1985) has shown that elimination of large woody debris can lead to excessive erosion, increased bedload movement, channelization and channel downcutting. Overgrazing can lead to erosion of banks creating obtuse angles and increased sedimentation (Platts 1979). Duff (1979) reported that introduction of cattle to stream banks that had been rested for 4 years resulted in eradication of bank overhang and increased erosion. With cessation of heavy grazing, the stream channel narrows and deepens, pool development is accentuated and stream banks stabilize as vegetation is established (Duff 1979; Hubert et al. 1985).

The removal of vegetation by cattle and the resultant erosion can have adverse effects on water quality. Excessive grazing by cattle has been shown to increase sediments within a watershed (Byron and Goldman 1989; Milne 1976). The addition of excessive levels of fine sediments results in conditions that are unfavorable to instream biota. For example, sedimentation has been shown to be a controlling factor for some species of fish and benthic macroinvertebrates (Chapman and MacLeod 1987; Rinne 1988b).

Intense livestock grazing may degrade the structural attributes of the plant community by decreasing woody vegetation which in turn may influence water quality. Claire and Storch (1977) observed that willow cover in an ungrazed exclosure on Camp Creek, Oregon provided 75% more shade to the stream than was provided in an adjacent grazed area with less willow cover. Platts and Nelson (1989a) found that ungrazed sites had more overstory canopy than did grazed areas and that canopy density and unobstructed sun arc were related to thermal inputs to the stream. Thermal inputs were inversely related to salmonid biomass. Benthic macroinvertebrates may be controlled by warmer water temperatures. According to Ward and Stanford (1982), insects with an aquatic life stage evolved in cooler, headwater streams. Therefore, warmer temperatures may be a constraint to those species that have not adapted to higher temperatures.

Excessive grazing by livestock may result in nutrient enrichment and increased coliform bacteria within the stream. Removal of riparian vegetation disrupts the riparian function of filtering nutrients and soil nitrification processes (Lowrance et al. 1984; Green and Kauffman 1989). In addition, manure is identified as a source of nitrogen and phosphorus (Gilbertson et al. 1979). Duff (1979) reported an increase in total and fecal coliforms in waters where intense cattle grazing occurs, as compared to protected or lightly grazed areas.

The consequences of excessive grazing on fish populations has received a great deal of attention in recent years. Fish populations may decline under conditions of intense grazing because of modifications of the functional attributes of riparian vegetation. According to Behnke and Zarn (1976), overgrazing has resulted in reductions of overhanging vegetation and loss of bank overhang which may be one of the leading factors contributing to the displacement of native trout in western states. Reduction of vegetative canopy can also result in increased water temperatures. Lynch et al. (1984) found that after vegetation removal, stream temperatures often exceeded temperatures that were tolerable to trout. Platts and Nelson (1989a) reported that thermal inputs were the best predictor of salmonid biomass in Rocky mountain headwater streams. Removal of canopy cover may also limit overwintering habitat for salmonids. Winegar (1977) compared grazed with ungrazed reaches and found heavy anchor ice in a grazed reach of an Oregon stream but limited anchor ice in an adjacent ungrazed site.

Numerous studies have examined the effects of grazing in riparian pastures on fish populations and habitat. Common approaches for these inquiries have been to compare stream reaches of differing grazing treatments or to observe changes after exclusion of cattle. Comparison of sections of stream subjected to varying intensity of livestock grazing generally show greater biomass of trout in ungrazed or lightly grazed pastures as compared to intensively grazed pastures (Hubert et al. 1985). Fisheries responses to improved habitat conditions after the exclusion of livestock, however, is quite variable. Several authors have reported increases in salmonid abundance and/or biomas in response to cessation of grazing (Duff 1979; Keller et al. 1979, Van Velson 1979). However, not all systems have responded with improvements in fish productivity after recovery of habitat (Hubert et al. 1985; Rinne 1988a). Because of the variation in response of fish populations to exclusion of cattle, it would be instructive to consider land uses and riparian conditions on the entire stream to identify what conditions result in a positive fishery response to management practices.

The effects of grazing on macroinvertebrate communities have not been extensively examined. Available information indicates that grazing can result in community changes in benthic macroinvertebrates in stream reaches subjected to intensive livestock grazing (Rinne 1988b). In degraded reaches, benthic fauna showed higher densities of species tolerant of sedimentation, high alkalinity and sulfates compared to non-impacted reaches. Grazing by cattle along streams may also diminish the availability of terrestrial sources of invertebrates. Comparison of the proportion of the annual diet comprised of terrestrial invertebrates among trout in an intensively grazed stream with an ungrazed stream showed higher consumption of terrestrial invertebrates in the ungrazed stream (Ensign 1957, cited in Hunt 1975).

Although there is limited information regarding the impacts of grazing on macroinvertebrates, assessing benthic communities has been suggested as a means of evaluating riparian conditions in streams (Platts et al. 1987). This approach involves using functional feeding guilds of benthic macroinvertebrates to assess the relative importance of allochthonous versus autochthonous organic inputs. This approach considers the ratio of shredder biomass and abundance to that of scrapers. Shredders should predominate in conditions of allochthony and, conversely, scrapers should be prominent in autochthonous systems. Evidence from other land use practices suggests that this type of evaluation may be sensitive to disruption of retention of organic matter. Land use practices that reduce streamside woody vegetation (i.e. logging or agriculture) and limit woody debris in a stream, may allow organic matter to be swept downstream and not processed locally. Smock et al. (1989) found that with increased debris dams, there was an increase in abundance of shredders as compared to areas without dams. The role of woody material in retaining organic material in streams subjected to different grazing schemes, however, has not been investigated.

Grazing Strategies and Sustainable Agriculture

As with most industries, agricultural production systems are coming under increased scrutiny as sources of environmental degradation and there is a growing recognition that the means of producing food, fiber and other human needs must be sustainable to ensure our long-term survival and well-being (Francis et al. 1990). Sustainable agriculture is a philosophy that has emerged to address a wide range of agricultural issues including both environmental quality and economic viability of farming systems. Specific concerns of sustainable agriculture include maintaining quality of surface and ground water, maintaining wildlife habitat and biodiversity, promoting forage availability and vigor, reduction of soil erosion, and preservation of rural ways of life (Francis et al. 1990; Edwards et al. 1990). Although, grazing management has received tremendous attention within the sustainable agriculture movement, the focus has been on upland areas (Francis et al. 1990; Edwards et al. 1990). Clearly, the benefits of proper riparian management (i.e. decreased erosion, increased forage, environmental protection, water quality maintenance) are compatible with the objectives of sustainable agriculture.

A number of grazing management strategies have been developed for upland areas to increase ground cover and plant vigor, encourage growth of favorable plant species and protect soil from erosion. These methods and their compatibility with fisheries were described by Platts (1989) with several of them having implications for sustainable agriculture. One practice relevant to my study is continuous, season-long grazing which involves grazing a pasture throughout the entire growing season. This method was deemed poorly compatible with fishery needs because even under light stocking rates, these areas can be severely impacted.

Another grazing strategy described by Platts, winter grazing, was considered to be moderately compatible with fisheries needs. This method was considered to be successful under conditions of dormant vegetation, frozen streambanks, light snow, and maintenance of ground cover, but no data were presented. Winter use of riparian pastures for calving is a common practice in Montana because cows and calves benefit from the thermal cover provided by riparian shrubs. However, little information exists on the effects of winter grazing on riparian areas. Because of the prevalence of this practice on private lands in Montana, investigation into potential impacts of winter grazing on riparian areas would be useful. A sustainable approach would be to allow use of riparian areas by cows and calves while preserving the function of the riparian ecosystem.

Riparian corridor fencing is considered to be highly compatible with fisheries needs (Platts 1989), although improvement in fish populations under this strategy has not been documented adequately (Platts 1991). According to Platts and Wagstaff (1984), fencing the riparian zone confers the maximum protection and the best opportunities for recovery in the shortest amount of time. However, this method may not be a sustainable alternative to many ranchers due to the significant expense involved. The economic costs include cost of fencing (up to $6,000 per mile in 1984), maintenance of the fence, and loss of forage (Platts and Wagstaff 1984). Development of an upland water source is another potential cost. There are numerous benefits, however, that can offset some of the expenditures such as fisheries values, recreational opportunities, wildlife habitat and water quality improvements. However, these potential benefits are not easily quantifiable in an economic sense.

There are a number of limitations to current knowledge on the impacts of grazing on riparian ecosystems. One consideration is the regional differences within the western United States and how applicable findings from the southwestern US and the Pacific northwest, where most research has been conducted, are to central Montana. Few studies have investigated the impacts of grazing on riparian ecosystems in southwestern Montana (Marlow et al, 1987; Marlow et al. 1989). Another limitation is that research investigating livestock grazing on riparian areas has been performed almost exclusively on public lands which may be managed quite differently than private ranches. There is a need to focus on the adaptability of existing information regarding grazing impacts to private ranch systems. For example, winter grazing on federal allotments is rare in Montana. In addition, while the effects of "intense" grazing have been documented, investigation of the response of riparian ecosystems and instream communities to a range of grazing strategies involving variation in timing, intensity and duration of livestock use has received little attention. Platts and Nelson (1985) investigated the impacts of rest-rotation on stream banks, stating this grazing strategy was the primary method used on many ranges. However, rest-rotation is only one of many strategies utilized by the ranching industry (Platts 1989).

My study is part of the western region SARE (Sustainable Agriculture Research and Education) Grants Program. The SARE project is a U.S. Department of Agriculture research and education effort which is involved in supporting the development and dissemination to farmers of practical and reliable information on sustainable practices (O'Connell 1988). The two overall objectives of this study are to: 1) assess how the structure and functions of riparian ecosystems respond to differing management strategies, and 2) suggest how these management strategies fit into the goals of sustainable agriculture. More specific objectives include measuring and comparing the responses of: riparian vegetation in terms of composition, structure, and abundance; stream bank morphology and stability; stream channel characteristics; fish habitat quality; fish abundance; retention of organic matter; potential contribution of terrestrial invertebrates; and, benthic macroinvertebrate communities and abundance. These comparisons were made between pastures under different management practices: long-term livestock exclusion (> 20 years); spring grazing; winter grazing; short-term livestock exclusion (5 years); and, continuous, season long grazing.

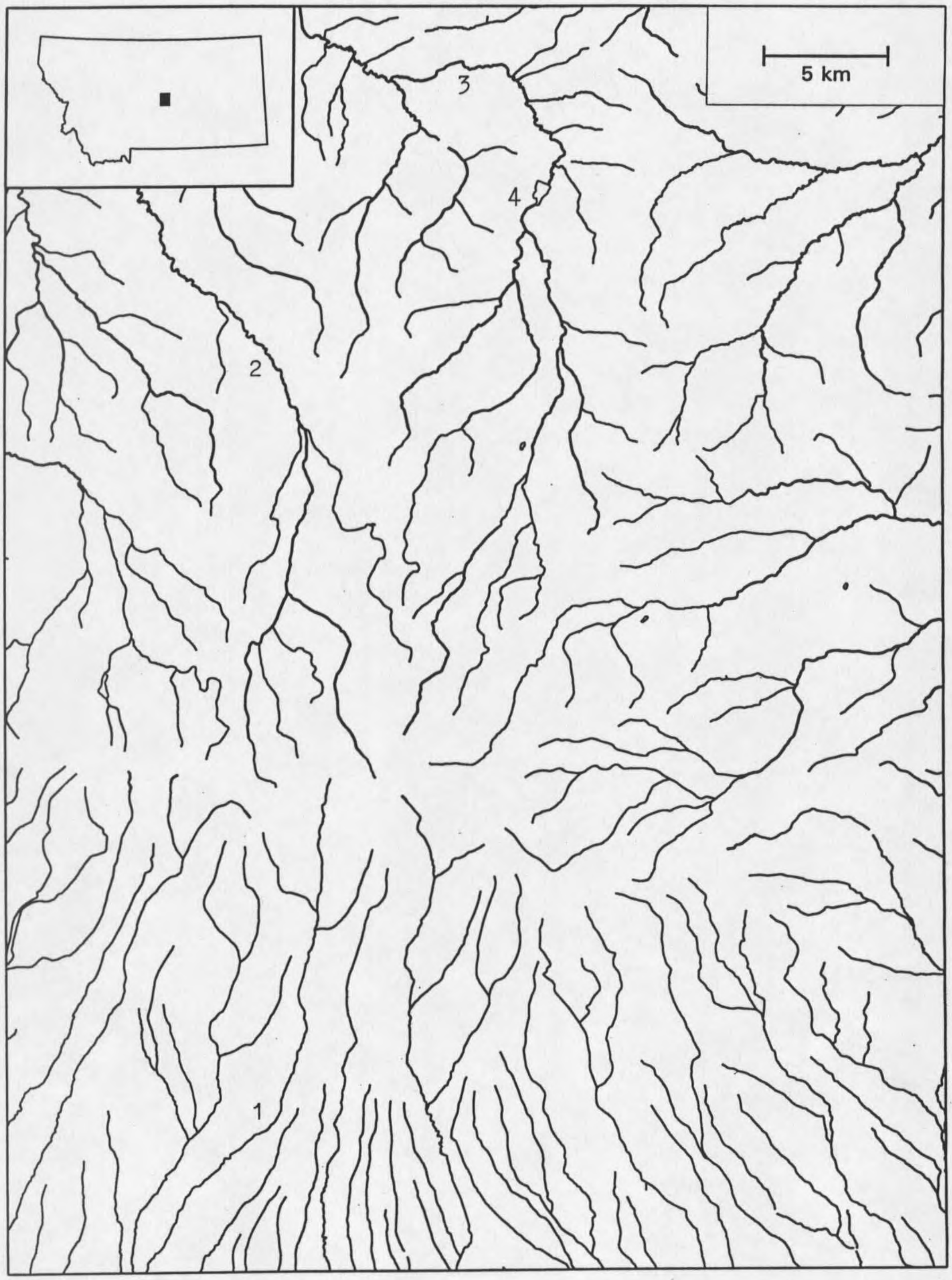

Figure 1. Map of eastern portion of the Snowy Mountains showing three study streams. 1= Careless Creek study site; 2 = Cottonwood Creek study site; 3 = East Fork Big Spring Creek study site; 4 = East Fork Big Spring Creek reservoir.

STUDY AREA

The study was conducted on three streams draining the Big Snowy Mountains in central Montana (Figure 1). Grazing management strategies on the three study ranches varied in intensity, duration and timing of livestock use.

Site 1: Careless Creek, long-term exclusion vs. seasonal grazing.

Careless Creek is located 20 km east of Judith Gap, Montana in Wheatland County. It is a second order stream draining the south side of the Snowy Mountains in the Musselshell River drainage. The riparian area is characterized as an *Alnus incana* (mountain alder) community type (Hansen et al. 1995). Much of the study area lies in the ecotone between forested foothills (*Pinus ponderosa*) and open rangeland. Land uses in the area include livestock grazing and hay cultivation. White-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*) and pronghorn (*Antilocapra americana*) are abundant in the area.

The two study sections on Careless Creek included an upstream spring-grazed section (grazed) and a downstream section that is fenced to exclude livestock grazing (fenced). The sections are separated by an area of beaver ponds (Figure 2). The grazed section consists of 462 m of stream on the western edge of a 3.5 ha pasture. A fence separates the pasture from a hay field to the west of the stream. Irrigation water is not drawn from or discharged into the stream in this area. The grazed section is grazed for a month each spring from mid-May to mid-June at a stocking rate of 3 acres/AUM (animal unit per month; D. Phillips, Fergus County extension agent, personal communication). The ungrazed section consists of 106 m of stream length. The fence is located between 30 and 100 m from the stream on the east side of the stream and between 10 and 30 m from the stream on the west side. The same grazing management strategies have been in effect for at least 20 years (J. Swanz, landowner, Judith Gap, Montana, personal communication).

Site 2: Cottonwood Creek, summer vs. winter grazing.

Cottonwood Creek is a third order stream located 10 km southwest of Lewistown, in Fergus County, Montana. An important aspect of this stream is the frequency and intensity of floods. Evidence of floods is in the form of numerous rubble bars suggestive of extensive and frequent bedload movement of relatively large substrate particles. Additional evidence of flooding is the presence of mats of organic matter deposited on shrubs on the streambank several meters away from the stream's edge. Because of the successional changes which result from frequent disturbance, numerous community types occur on this stream including mountain alder community type, sandbar willow (*Salix exigua*) community type, *Populus trichocarpa*/recent alluvial bar community type and *Populus trichocarpa*/*Cornus stolonifera* community type (Hansen et al. 1995). Upland land uses include livestock grazing and hay cultivation. White-tailed deer are abundant in the study area.

Grazing management strategies on this stream included an upstream summer-grazed pasture consisting of 820 meters of stream length and a 1025 m downstream winter-grazed section (Figure 3). The summer-grazed pasture is used for yearling cattle from July through August at a stocking rate of 3 acres/AUM (D. Phillips, personal communication). The winter-grazed section is used during calving from January through March at a stocking rate of 3 acres/AUM. Hay is provided in the uplands. Both pastures are about 2.5 ha in size. The landowner reports that these grazing management strategies have been utilized for between 20 to 40 years.

Site 3: East Fork Big Spring Creek, short-term exclosure vs. seasonal grazing.

East Fork Big Spring Creek is a third order stream located 6 km southeast of Lewistown in Fergus County, Montana. In the 1970's a flood control reservoir was built 4.5 river km above the study site. Surface water release is via a standpipe, but flows are augmented below the impoundment by groundwater and dam seepage. Livestock grazing and hay/alfalfa cultivation are primary land uses in the area. Irrigation water is withdrawn near the upper end of the fenced section. White-tailed deer are abundant. Riparian degradation in the form of vegetation removal and resulting erosive, incised banks occur along much of East Fork Big Spring Creek between the dam and the study site.

In 1988, the landowner, with assistance from the Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service) fenced the riparian corridor to exclude livestock along the stream for about 1 km. Additional improvements included the development of an upland water source and addition of tree revetments to several highly eroded banks. A series of before and after photographs were taken by the NRCS at a series of permanent photo-points to document the changes in the fenced section. This section had been used as a winter pasture for several decades and there was evidence of severe bank degradation. Photographs taken at the time of fencing showed highly eroded and extensive downcutting (up to 3 meters in some places).

The two study sections included a fenced section (1100 m) and a downstream grazed section (205 m) that served as a control to assess the recovery following fencing (Figure 4). The grazed section is generally grazed throughout the summer by several horses and steers at a stocking rate of 5 acres/AUM. The pasture is approximately 0.5 ha in size. The riparian communities differed between the sections. The ungrazed section is a sandbar willow community type, while the grazed section is a Kentucky bluegrass (*Poa pratensis*) community type.

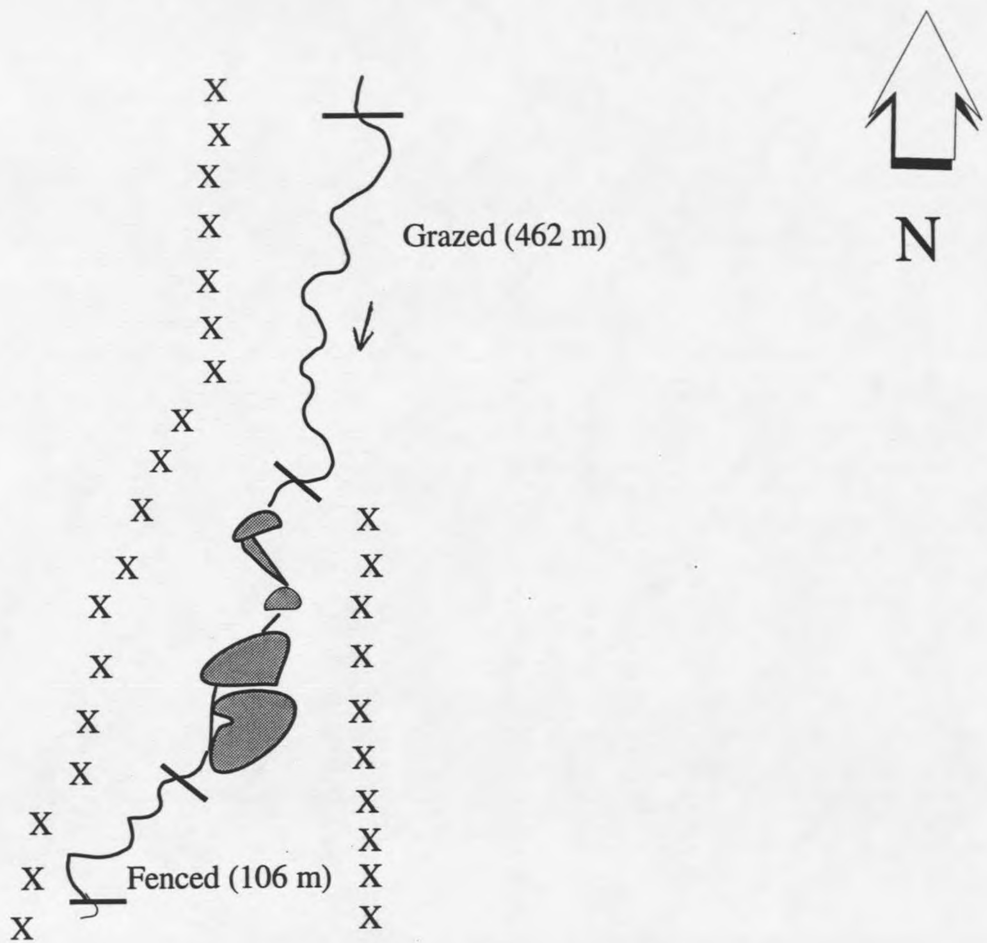

Figure 2. Schematic representation of Careless Creek study site showing upper grazed treatment, area of beaver ponds and lower, fenced treatment. Fencing is represented by X's.