1987

Habitat Use by Beaver Along the Big Sioux River

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HABITAT USE BY BEAVER ALONG THE BIG SIOUX RIVER

BY
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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Wildlife and Fisheries Sciences (Wildlife option)
South Dakota State University
1987

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor

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ACKNOWLEDGEMENTS

I extend my sincere thanks and appreciation to my advisor, Dr. Thomas R. McCabe, for his assistance throughout this project. Special appreciation is also extended to Dr. L. D. Flake for his friendship, Dr. G. E. Larson for his dedication, and Dr. K. F. Higgins for his insight. I also wish to thank Dr. W. L. Tucker for providing valuable assistance during statistical analyses.

Thanks is extended to J. Stander, and all graduate and undergraduate students who assisted with the study. I am grateful to B. Jensen, J. Reidel, L. Anderson, and J. Herbst for their cooperation and help throughout this study.

Lastly, I am indebted to my wife Carla for her faith, love, and understanding and to my beloved children Rachel and Nicholas for being themselves. I am grateful to my parents, Don and Elaine, for their absolute support.

Funds for this project were provided by the South Dakota Agricultural Experiment Station and South Dakota Department of Game, Fish and Parks.

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HABITAT USE BY BEAVER ALONG THE BIG SIOUX RIVER

ABSTRACT

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Habitat utilization and lodge site selection by beaver (*Castor canadensis*) were investigated during 1985 and 1986 along the Big Sioux River in eastern South Dakota. Because livestock grazing has affected the number and size of trees available for beaver use, the study area was portioned into grazed, ungrazed, and farmed habitat. Diameter at breast height (DBH) of trees in grazed areas was greater ($p < 0.01$) than in ungrazed or farmed areas. Almost half (48%) of the trees in ungrazed areas were small (DBH < 7.5 cm), while a majority (58%) of the trees in grazed areas had large diameters (DBH > 30 cm).

Beaver activity was evident on 286 of 2410 (11.8%) trees (DBH > 2.5 cm) and 756 of 7,794 (9.7%) stems (DBH < 2.5cm) sampled. A greater proportion ($p < 0.01$) of trees were cut by beavers in ungrazed than in grazed areas. Beaver did not select tree species for cutting according to availability ($p < 0.01$). Green ash (*Fraxinus pennsylvanica*) was selected for cutting while both boxelder (*Acer negundo*) and hawthorn (*Crataegus mollis*) were selected against. Sandbar willow (*Salix exigua*) stems were important for food and building materials. Trees cut by beaver were significantly smaller in diameter ($p < 0.01$) than uncut

trees. Mean distance from water of cut trees was also less ($p < 0.01$) than for uncut trees. Over half (52%) of the trees damaged by beaver were not killed and either resprouted or remained alive and standing.

Of 8 variables examined at lodge sites, analysis indicated that the 2 most important factors in beaver lodge site selection were riverbank slope and horizontal cover density between 0.9 m and 1.8 m above ground (read from 10 m). Mean slope of the riverbank at lodge sites (40.7 degrees) was greater ($p < 0.01$) than at control sites (26.7 degrees), while mean horizontal cover density between 0.9 m and 1.8 m (read from 10 m) was also greater ($p < 0.01$) at lodge sites (53%) than at control sites (28%).

Ungrazed habitat was selected by beaver for lodge sites, and grazed areas were selected against. Although 40% of the study area was ungrazed, 27 of 33 (82%) active lodges were located in these areas. Ungrazed areas along the Big Sioux River are important for beaver populations and selection for these areas by beaver reflects habitat quality.

BEAVER HABITAT USE ALONG THE BIG SIOUX RIVER

INTRODUCTION

The fur trade initiated exploration of the Dakota Territory in the early 19th century and trappers working along the rivers and streams of the northern Great Plains found an abundance of beaver (*Castor canadensis*), a highly prized fur bearer. Philander Prescott, the first white man known to enter the earliest Brookings County settlement of Medary, wrote: "In 1832 I was ordered to prepare for Crooked river, or Big Sioux... The object of these posts in this forlorn and barren country was that it was reported that large quantities of beaver were to be found in the Big Sioux and its tributaries" (Harris and Aldous 1946).

As the fur industry flourished, beaver were trapped extensively in the northern plains causing populations to plummet (Grasse and Putnam 1950). With the influx of European settlers onto the prairies, agriculture became the primary source of income and interest in trapping waned allowing beaver populations to increase. As agricultural activity steadily increased in this century, beaver trapping for recreation and as a source of income has fluctuated with fur prices and beaver availability. However, with the use of traditional beaver habitat for agriculture, beaver have changed in status from that of a valuable economic entity to one of being a nuisance animal (Anderson 1964).

In South Dakota, harvest of beavers for fur has been considered its primary mortality factor (Vanden Berge and Vohs 1977), but because of low fur prices in recent years, beaver populations have been increasing. The ability of beaver to alter their environment is often in conflict with man, as witnessed by South Dakota Division of Game, Fish and Parks (SDGF&P) records, which show that complaints concerning damage caused by beavers to agricultural crops and riparian vegetation have burgeoned in recent times (Miller 1985).

Increased beaver populations in eastern South Dakota have caus'i oocern as to whether beaver are accelerating the destruction of riparian habitat in concert with agricultural activities along the Big Sioux River and its tributaries. Livestock grazing is detrimental to riparian habitat (Minckler 1975), and has seriously affected the Big Sioux River valley by causing existing riparian habitat to be degraded or lost (Smith and Flake 1983). The protection of riparian habitat is of primary concern in eastern South Dakota because it discourages soil erosion, stabilizes riverbanks, and provides habitat for many resident and migratory species of wildlife.

To date no documented studies dealing with beaver impacts on riparian habitat along the Big Sioux River drainage have been conducted. Previous studies dealing with tree selectivity and habitat use by beaver have been conducted primarily in montane or forest habitats (Chabreck 1958, Northcott 1971, Roberts and Arner 1984). Few studies dealing with habitat utilization by beaver have been done in the northern plains.

Beavers live in family groups or colonies which generally consist of an adult pair and one or more sets of offspring (Bradt 1938, Hay 1958, Aleksiuk 1968), but many variations of this pattern occur (Bergerud and Miller 1977). Colonies can be identified by the presence of a lodge that consists of sticks and mud and serves as a residence for the colony (Bailey 1927). Selection of a lodge site by beaver can be influenced by population levels (Bradt 1938), habitat quality (Slough and Sadleir 1977, Jenkins and Busher 1979) and territoriality (Aleksiuk 1968). However, a paucity of research data is available to predict those physical and vegetative factors that influence selection of lodge sites. Information gathered on factors affecting lodge site selection by beavers could help wildlife personnel in efforts to identify and manage existing beaver habitat.

This study provides information on habitat use and lodge site selection by beaver along the Big Sioux River in eastern South Dakota. The ability to manage this beaver population and at the same time protect valuable riparian habitat is dependent on understanding the ecology of the beaver.

The objectives of this study were to:

1) compare riparian vegetation utilization by beaver in habitat grazed by domestic livestock and ungrazed areas.

2) identify tree species utilized by beaver and determine size and distance from water of trees cut by beaver.

3) determine if beaver are selecting for specific, identifiable habitat characteristics for lodge sites.

This thesis is divided into 2 chapters in accordance with the objectives of the study. Chapter One addresses the first 2 objectives dealing with riparian habitat use by beaver, and Chapter Two pertains to lodge site selection.

CHAPTER 1

TREE SELECTION BY BEAVER ALONG THE BIG SIOUX RIVER

Beaver populations have dramatically increased throughout eastern South Dakota according to data collected by SDGF&P (Miller 1985). This population increase is attributed to low fur prices in recent years which have caused a reduction in harvest of beavers. At the same time, traditional beaver habitat, such as riparian forests along the Big Sioux River drainage, has been degraded or lost due to agricultural activities (Smith and Flake 1983). An i.icrease in beaver populations in areas altered by agricultural practices may cause acceleration of damage to existing riparian habitat along the Big Sioux River drainage. Large numbers of beaver concentrated in remaining areas of quality habitat may cause damage to the riparian community.

The purpose of this investigation was to measure the use of riparian tree species by beaver and to determine the impact of this activity on the forest community in grazed and ungrazed areas.

STUDY AREA

The study area was located in Brookings and Medary townships in Brookings county and Campbell township in Moody county in east-central South Dakota along the Big Sioux River (Fig. 1). Included in the study area were the main and secondary channels as well as oxbow lakes and inundated depressions adjacent to the river. Three major drainages, North Deer, Six Mile, and Medary creeks enter the Big Sioux River within the study area.

The climate of the area is continental with annual temperature extremes ranging from -29C to 38C and an average annual precipitation of 52.3 cm (Spuhler et al. 1971). However, according to South Dakota State University Weather Research Laboratory, during 1986 eastern South Dakota experienced record amounts of precipitation (76.6 cm) which caused unusually high water levels in the Big Sioux River and the surrounding region.

The Big Sioux River, which originates north of Watertown in Grant county, South Dakota and flows in a southerly direction to enter the Missouri River at Sioux City, Iowa, is the primary drainage in this region of the Coteau des Prairie. The headwaters have an elevation of about 550 m above sea level which drop to about 330 m at its confluence with the Missouri River. The river occupies a broad, shallow valley from its source to the vicinity of Sioux Falls. A unique feature of the Big Sioux River Basin

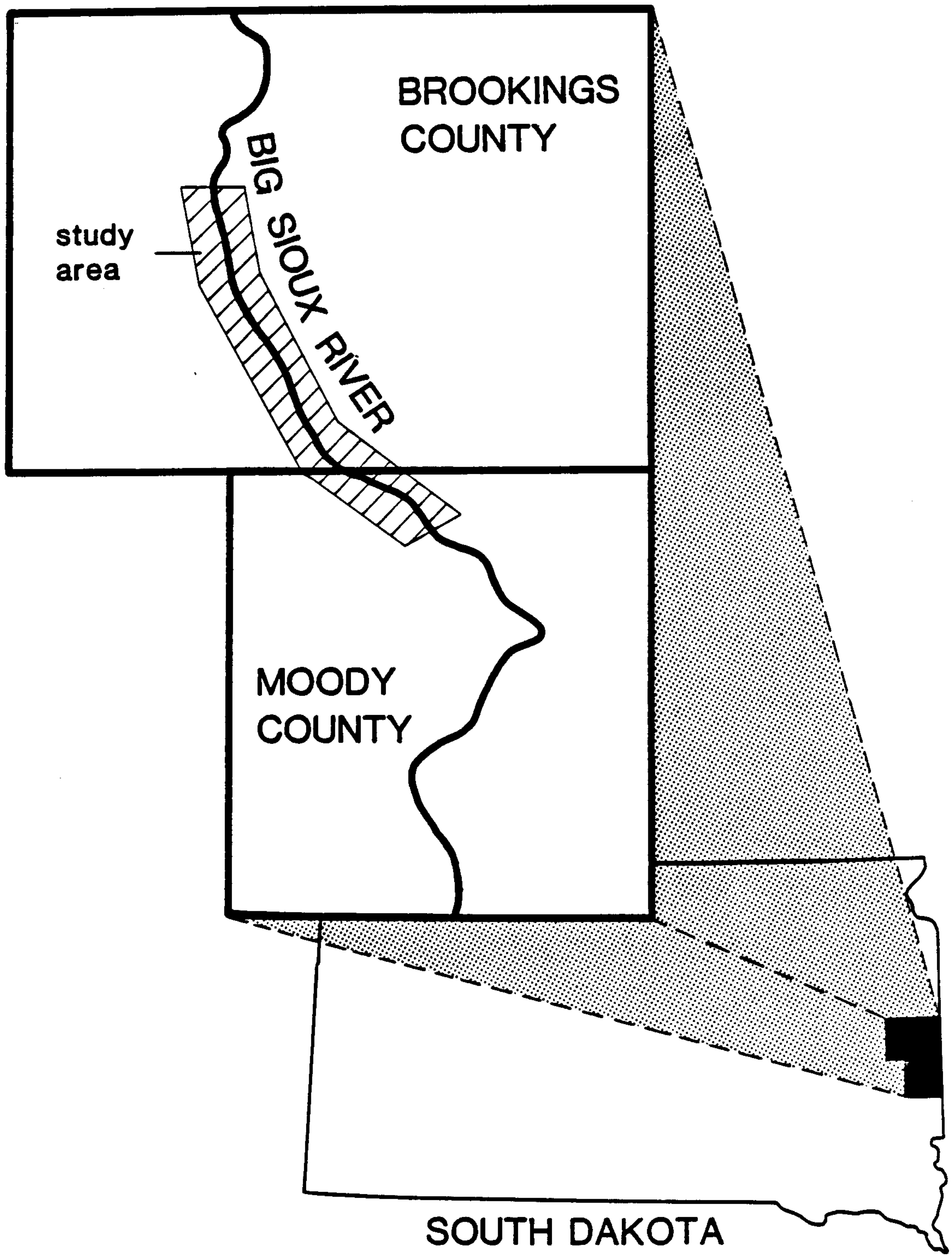

Figure 1. Location of the 1985 and 1986 study area for beaver along the Big Sioux River in Brookings and Moody counties of eastern South Dakota.

is that almost all of the tributaries enter from the east, while west of the river the drainage area contains numerous potholes, marshes, and lakes, but very few streams.

Stream flow in the Big Sioux River varies throughout the year, with highest flows normally in spring months. The floodplain is usually inundated annually as spring runoff from a large area flows into the Big Sioux River. Width of the river channel within the study area varies from 15 to 40 m. The river depth ranges from 0.3 to 1.7 m. Winter freeze-up of the river on the study area usually occurs in Dece:nber and spring break-up generally takes place in March.

Land along the Big Sioux River is classified as Solomon clay soil type (Westin and Maio 1978). Soils along the hottomlands of the Big Sioux are level and medium- to fine-textured. The river bed consists mainly of shifting sand and small gravel while silt beds are found in quiet backwaters. Current speed varies with water levels and the river usually carries a heavy silt load.

Riparian tree and large shrub species commonly found in the study area are green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), peachleaf and sandbar willow (*Salix amygdaloides* and *S. exigua*), and american elm (*Ulmus americana*). Species found occasionally throughout the area are hawthorn (*Crataegus mollis*), hackberry (*Celtis occidentalis*), Tartarian honeysuckle (*Lonicera tatarica*), American plum (*Prunus americana*), and cottonwood (*Populus deltoides*).

Agricultural land use in eastern South Dakota is primarily cultivation of small grain and corn with some areas utilized for livestock production. Along the Big Sioux River, corn is the primary grain crop and is often planted in close proximity to the river channel. Grazing of livestock, primarily cattle, occurs on approximately 55% of land adjacent to the Big Sioux River (Smith and Flake 1983).

The negative impacts of intensive agricultural activity on a riverine system are evident throughout the study area. Examples included such things as planting of row crops directly adjacent to the river channel resulting in soil erosion, dumping of trash and junked machinery into the river, trampling of riverbanks by cattle, and draining of effluents from feedlots.

Livestock grazing has altered previously existing riparian habitat. Grazed areas are characterized by a few scattered large trees with no regeneration and little understory. Ungrazed areas have thick understory growth and an abundance of small trees interspersed with large trees (Smith and Flake 1983).

METHODS

From May to August 1986, an area encompassing approximately 23 km of the Big Sioux River was surveyed in an effort to quantify existing riparian habitat and estimate beaver utilization of riparian tree and shrub species. Sample quadrats were defined as variable-length strip transects 3 m wide with their respective lengths being the distance in meters from the shoreline to the outer edge of wooded habitat. Quadrats were randomly located along the Big Sioux River, as well as all backwaters in old river channels, within the study area. Quadrat locations were assigned by starting at a random point in the first 100 m of the study area and then traveling downstream in a motorized craft, stopping at random time intervals between 1 and 30 seconds. A coin toss was then used to determine on which side of the river to place the quadrat.

To survey a quadrat, a 3m rod was held at its midpoint by me while walking towards a fixed point perpendicular to the river. All woody plants contacted by the rod were considered to be in the quadrat and were listed by species. Woody trees and shrubs encountered were grouped according to diameter at breast height (DBH), as stems (DBH < 2.5 cm) or trees (DBH > 2.5 cm). A tape measure was used to measure distance from the tree or stem to open water and the total length of the transect. Trees and stems that were alive or had been damaged by beaver were included in the sample, while those that were dead were omitted.

The riparian habitat in the study area was categorized according to land use as: 1) grazed, adjacent to the main river channel (GR), 2) non-grazed, adjacent to the main river channel (NGR), 3) grazed, adjacent to old river channels (GO), 4) non-grazed, adjacent to old river channels (NGO), or 5) farmed (F). Actual density (AD = Number of trees of species A/ha), relative density (RD = Number of trees of species A/total number of trees x 100), actual basal area (ABA = basal area of species A/ha), and relative basal area (RBA = basal area of species A/total basal area of all species x 100) were calculated for all trees and by tree species for the entire riparian community as well as for the 5 habitat classifications. The use of frequency as a means of comparison was not valid due to the variable quadrat size. Categorical data modeling was used to compare tree density and total basal area between habitat divisions.

All trees and stems sampled were inspected for beaver damage and were recorded as either damaged or undamaged. Those trees or stems that had been. damaged by beaver were further separated by extent and type of cutting: 1) fresh cuts, 2) old cuts, 3) alive and standing but damaged, and 4) cut with resprouting. Fresh cuts were defined as cuts occurring in the post-winter period of the current year as determined by the observer. Old cuts were defined as those trees that were cut by beaver in a previous year and did not survive due to the damage. The third category included trees which had suffered obvious beaver damage, but were not killed by this activity. Examples were large trees which had been cut only partially through the trunk and trees which had been stripped of bark. Trees or stems which had been cut by beaver often exhibit regrowth around the stump, and those encountered in the sample were grouped as cut with resprouts.

The effects of beaver activity on trees and stems were separated into these 4 groups in order to assess the net impact of beaver on the forest environment. Although damaged, trees in category 3 had not been altered sufficiently to decrease their benefit to the ecosystem. In some cases, trees that resprout have not had decreased growth rates or basal diameter due to vigorous new growth (Kindschy 1985).

Relative cuts (Cr = Number of trees of species A cut/total trees cut x 100) were calculated for all tree species. Chi-square analysis was used to test if beaver selected tree species in proportion to their availability in the study area. If there were significant differences, :onfidence intervals were constructed around the proportion of observed use of the tree species to determine selection or avoidance (Neu et al. 1974, Byers and Steinhorst 1984). A chi square test was also used to test if beaver were cutting trees in equal proportions in all habitat types. Analysis of variance was used to determine if there was a difference in DBH and distance from water of all trees among habitat divisions, and to determine size of trees and distance from water of trees selected for cutting by beaver.

RESULTS

During 1986, a total of 509 quadrats, which had a combined distance of 24.8 km and encompassed an area of 7.42 hectares, was sampled along the Big Sioux River. In the study area, 55% of the forest was not grazed (38% NGR, 17% **NGO), 39%** was grazed (25% GR, 14% GO), and 6% was farmed (Table 1). Eleven species of trees were encountered in the quadrats (Table 2). Silver maple (A. saccharinum) and Russian olive (Elaeagnus angustifolia) were omitted from analyses due to small sample size.

Analysis of variance using least square means showed that there was no significant difference ($p = 0.73$) in mean DBH between trees in NGO (20.1 cm) and NGR (20.5 cm), so these 2 divisions were combined. DBH in GO (38.6 cm) and GR (37.1 cm) areas were not significantly different ($p = 0.50$) and were also combined. Mean DBH of trees in F (20.5 cm) areas was not significantly different from NGO or NGR ($p = 0.90$), but was significantly less ($p < 0.01$) than GO and GR. The mean distance of trees from water in F (5.2 m) was significantly less ($p < 0.01$) than NGR (24.4 m) and NGO (20.5 m) so F areas were not combined with ungrazed habitat. The forested habitat types were grouped as grazed, ungrazed, and farmed for comparison of beaver use.

The forest community structure was quite different between habitat types. Grazed areas were characterized by a few large trees with few young trees present, while

Table 1. Quadrats sampled in 5 habitats along the Big Sioux River in eastern South Dakota grouped as ungrazed adjacent to main river channel (NGR), grazed adjacent to main river channel (GR), ungrazed adjacent to old river channels (NGO), grazed adjacent to old river channels (GO), and farmed for crop production (F).

Habitat	Quadrat Length (m)	Quadrat Area (ha)	Number of quadrats	Percent of study area
NGR	10,070	3.02	195	38.3
GR	6,953	2.08	126	24.8
NGO	3,448	1.03	86	16.9
GO	3,686	1.10	69	13.6
F	642	.19	33	6.4
Total	24,799	7.42	509	100.0

Table 2. Number of 11 tree species and percentage of each sampled along the Big Sioux River in eastern South Dakota in 5 habitats: ungrazed adjacent to main river channel (NGR), grazed adjacent to main river channel (GR), ungrazed adjacent to old river channels (NGO), grazed adjacent to old river channels (GO), and farmed for crop production (F).

Species	NGR	GR	NGO	GO	F	TOTAL	PERCENT
Green ash	518	157	194	113	8	990	41.1
Boxelder	315	42	138	27	13	535	22.2
American elm	99	37	97	18	14	265	11.0
Peachleaf willow	97	60	35	50	3	245	10.2
Hawthorn	119	21	88	3	0	231	9.6
Tartarian honeysuckle	43	11	11	1	0	66	2.7
Hackberry	10	1	16	8	0	35	1.5
American plum	10	2	13	1	3	29	1.2
Cottonwood	5	2	5	2	0	14	0.5
Sugar maple	1	0	2	1	0	4	0.0
Russian olive	0	0	2	0	0	2	0.0
Total	1,216	333	597	223	41	2,418	100.0

ungrazed areas had an abundance of small trees interspersed with large trees. In grazed areas, 28 of 195 quadrats contained no trees, while in ungrazed areas only 1 of 281 quadrats was not forested. Riparian habitat in farmed areas was sometimes nonexistent as almost half (15 of 33) of the quadrats sampled were devoid of trees. In areas where crops were not planted directly adjacent to the river channel, an abundance of small trees and stems were present in the short distance between the river and the grain field. Ash and peachleaf willow trees, most of which were old and large, were common in grazed areas. Ash was also most abundant in ungrazed areas, while both boxelder and elm were more common in ungrazed than in grazed areas (Table 3). Boxelder and elm were most common in farmed areas. Tartarian honeysuckle, hackberry, plum, and cottonwood were present only occasionally in both grazed and ungrazed sections.

Actual tree density was significantly higher ($p < 0.01$) in ungrazed areas than in grazed and farmed areas (Table 3). All species except peachleaf willow had higher actual densities in ungrazed areas than in grazed areas (Table 3). Ash, peachleaf willow, and hackberry had higher relative densities (RD) in grazed areas than in ungrazed areas. All other species had greater relative densities in ungrazed areas than in grazed areas.

Analysis of variance indicated that there was a significant difference in DBH among habitat divisions (p

Table 3. Actual density (AD = trees/ha) and relative density (RD = trees of species A/total trees x 100) of 9 tree species along the Big Sioux River of eastern South Dakota by habitat classification.

Species	Ungrazed		Grazed		Farmed	
	AD	(RD)	AD	(RD)	AD	(RD)
Green ash	178	(40)	84	(49)	42	(20)
Boxelder	113	(26)	21	(12)	68	(32)
American elm	49	(11)	17	(10)	74	(34)
Peachleaf Willow	33	(7)	34	(20)	16	(7)
Hawthorn	51	(11)	8	(5)	0	(0)
Tartarian honeysuckle	13	(3)	4	(2)	0	(0)
Hackberry	6	(1)	3	(2)	0	(0)
American plum	6	(1)	1	(0)	16	(7)
Cottonwood	3	(1)	1	(0)	0	(0)
Total	452	(100)	173	(100)	216	(100)

Chi square = 153.23** 16 df

Significant at the 0.01 level

0.01, 2 d.f.). Analysis of least square means showed a significant difference ($p < 0.01$) in DBH between grazed areas (37.7 cm) and ungrazed areas (20.4 cm). Mean DBH value in farmed areas (20.5 cm) was also significantly lower ($p < 0.01$) than in grazed areas. There was no difference in mean DBH between ungrazed and farmed areas ($p = 0.96$). Mean DBH values for most species were higher in grazed areas than ungrazed areas (Appendix 1). In ungrazed areas almost half (48%) of the trees had a DBH under 7.5cm, while a majority (58%) of the trees in grazed areas had a DBH greater than 30 cm (Table 4).

Total basal areas were significantly ($p < 0.01$) different between habitat divisions, but basal areas of green ash and willow were similar in grazed and ungrazed areas (Table 5). Relative basal area was much greater for both species in grazed areas, indicating that other species are not thriving in grazed habitats. Total basal area of most other tree species was greater in ungrazed habitat.

Sandbar willow was the most common species in the stem category, comprising 90% of all stems encountered. In the remaining sample, only ash (5%) made up more than 1% of available stems. Stems were abundant in ungrazed and farmed areas, but few stems were located in grazed areas (Table 6). Willow stems were often clustered in dense thickets at or very near the shoreline, especially in ungrazed habitat.

Table 4. Size-class distribution of 9 tree species based on diameter at breast height (DBH) in grazed and ungrazed habitats along the Big Sioux River in eastern South Dakota in 1986.

DBH cm	Grazed		Ungrazed	
	N	%	N	(%)
2.5-7.5	90	(16)	880	(48)
7.6-15.0	39	(7)	254	(14)
15.1-30.0	107	(19)	257	(14)
30.1-50.0	178	(32)	224	(12)
50.1 and over	145	(26)	203	(11)
Total	559		1818	

Table 5. Total basal area (TBA = square cm/ha) and relative basal area (RBA = Total basal area of species A/total basal area x 100) determined from diameter at breast height (DBH) of major tree species along Big Sioux River by habitat classification.

Species	Habitat: Grazed TBA	(RBA)	Ungrazed TBA	(RBA)	Farmed TBA	(RBA)
Green ash	143,060	(48.7)	142,548	(39.0)	43,237	(23.1)
Peachleaf willow	100,680	(34.3)	112,660	(30.8)	94,037	(50.1)
Boxelder	32,673	(11.3)	78,035	(21.4)	45,705	(24.4)
Cottonwood	9,240	(3.1)	17,353	(4.8)	0	(0)
American elm	4,125	(1.4)	5,906	(1.6)	4,547	(2.4)
Hawthorn	795	(0.3)	5,570	(1.6)	0	(0)
Hackberry	2.700	(0.9)	2,270	(0.6)	0	(0)
Tartarian honeysuckle	200	(0.1)	576	(0.2)	0	(0)
American plum	5	(0)	120	(0)	79	(0)
Total	293,478	(100)	365,488	(100)	187,605	(100)

Chi square = 80.42** 16 df

**Significant at the 0.01 level

Table 6. Stem density (DBH < 2.5cm) and number of stems cut by beaver along the Big Sioux River in eastern South Dakota in 1986 by habitat classification.

Habitats	N	Stem Density (stems/ha)	Stems cut (%)	Density (stems cut/ha)
Ungrazed	6,380	1,595	551 (8.6)	138
Grazed	605	189	50 (8.2)	16
Farmed	809	4,258	155 (19.1)	775
Total	7,794	1,060	756 (9.7)	102

Chi square = 81.91** with 2 df

** Significant at the 0.01 level

Beaver cuts

Beaver activity was evident on 286 of 2,410 trees (11.8%) and 756 of 7,794 stems (9.7%) sampled. A significantly higher percentage ($p < 0.01$) of stems were cut in farmed areas than in both grazed and ungrazed areas (Table 6). Ungrazed and farmed areas had a significantly higher percentage ($p < 0.01$) of trees cut than grazed areas (Table 7).

Ash was the most utilized tree species, comprising nearly **69%** of those trees cut by beaver (Fig. 2). Chi square analysis (Table 8) indicated that beaver did not select trees for cutting according to their availability ($p < 0.01$). Ash was selected for while both boxelder and hawthorn were selected against (Table 9).

Analysis of variance found a significant difference ($p < 0.01$) in mean DBH between trees that were cut (13.7 cm) and those uncut (25.8 cm) by beaver. For all species combined, beaver selected trees of smaller diameter to cut (Fig. 3). When comparing each species separately, the mean DBH of cut trees was less than for uncut trees for all species except hawthorn and significantly lower ($p < 0.01$) for ash, boxelder, and willow (Table 10). The mean DBH (31.0 cm) of trees cut by beaver in grazed areas was smaller, but not significantly so ($p = 0.14$) than the mean DBH (38.7 cm) of uncut trees. The mean DBH (11.8 cm) of cut trees in ungrazed areas was significantly less (p

Table 7. Density of trees (DBH > 2.5cm) damaged by beaver along the Big Sioux River in eastern South Dakota in 1986 by habitat classification.

Land Use	N	Trees cut	(%)	Density (Trees cut/ha)
Ungrazed	1,813	251	(13.8)	62.0
Grazed	556	29	(5.2)	9.1
Farmed	41	6	(14.6)	31.6
Total	2,410	286	(11.8)	38.4

Chi-square = 27.44** with 2 df

** Significant at the 0.01 level

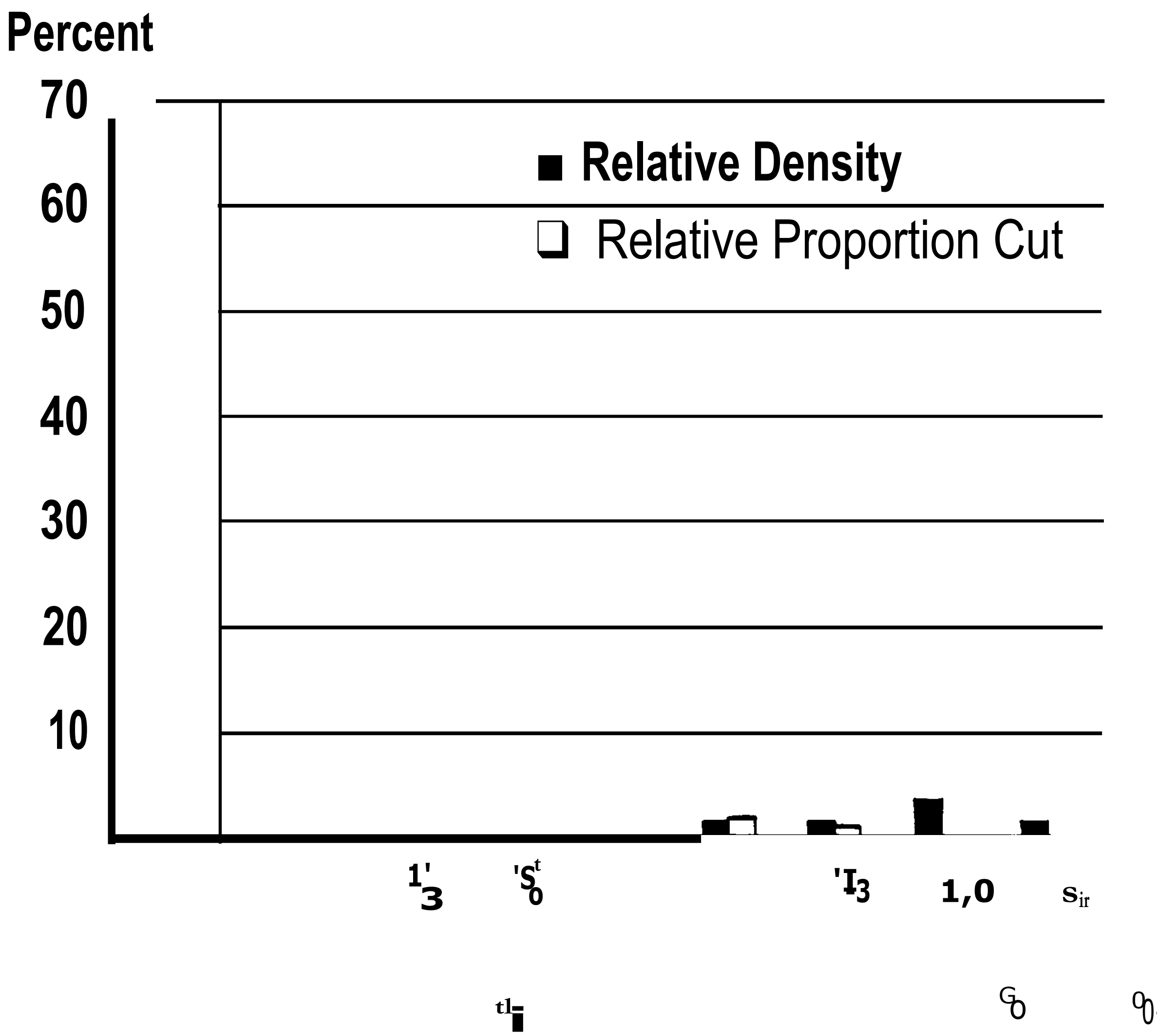

Figure 2. Relative density of tree species vs. relative proportion of tree species cut by beaver along the Big Sioux River, South Dakota, in 1986.

Table 8. Proportion of trees sampled by species and those cut by beaver along the Big Sioux River in eastern South Dakota during summer 1986.

Species	Proportion of trees sampled (N)	Proportion of trees cut (N)	(%)
Green ash	.41(990)	.69(187)	(19.9)
Peachleaf willow	.10(245)	.11(30)	(12.2)
American elm	.11(265)	.09(26)	(9.8)
Boxelder	.22(535)	.06(18)	(3.3)
Hawthorn	.10(231)	.035(10)	(4.3)
Hackberry	.01(35)	.014(4)	(11.4)
American plum	.01(29)	.004(1)	(3.5)
Cottonwood	.01(14)	.000(0)	(0)
Tartarian honeysuckle	.03(66)	.000(0)	(0)
Total	2410	286	

Chi square = 124.44** with 8 df

**Significant at the 0.01 level

Table 9. Tree species selection or avoidance (95% confidence interval) by beaver along the Big Sioux River in eastern South Dakota.

Tree species	Proportion available	Proportion observed	95% CI on proportion observed
Green ash	.41	.6895	.618 < P_1 < .760
Peachleaf willow	.10	.105	.058 < P_2 < .152
American elm	.11	.091	.047 < P_3 < .135
Boxelder	.22	.062a	.025 < P_4 < .099
Hawthorn	.10	.035a	.006 < P_5 < .064
Hackberry	.01	.011	.004 < P_6 < .016
American Plum	.01	.004	.000 < P_7 < .010
Cottonwood	.01	.000	
Tartarian honeysuckle	.03	.000	

a = avoidance (proportion of available trees > upper confidence limit);

s = selection (proportion of available trees < lower confidence limit).

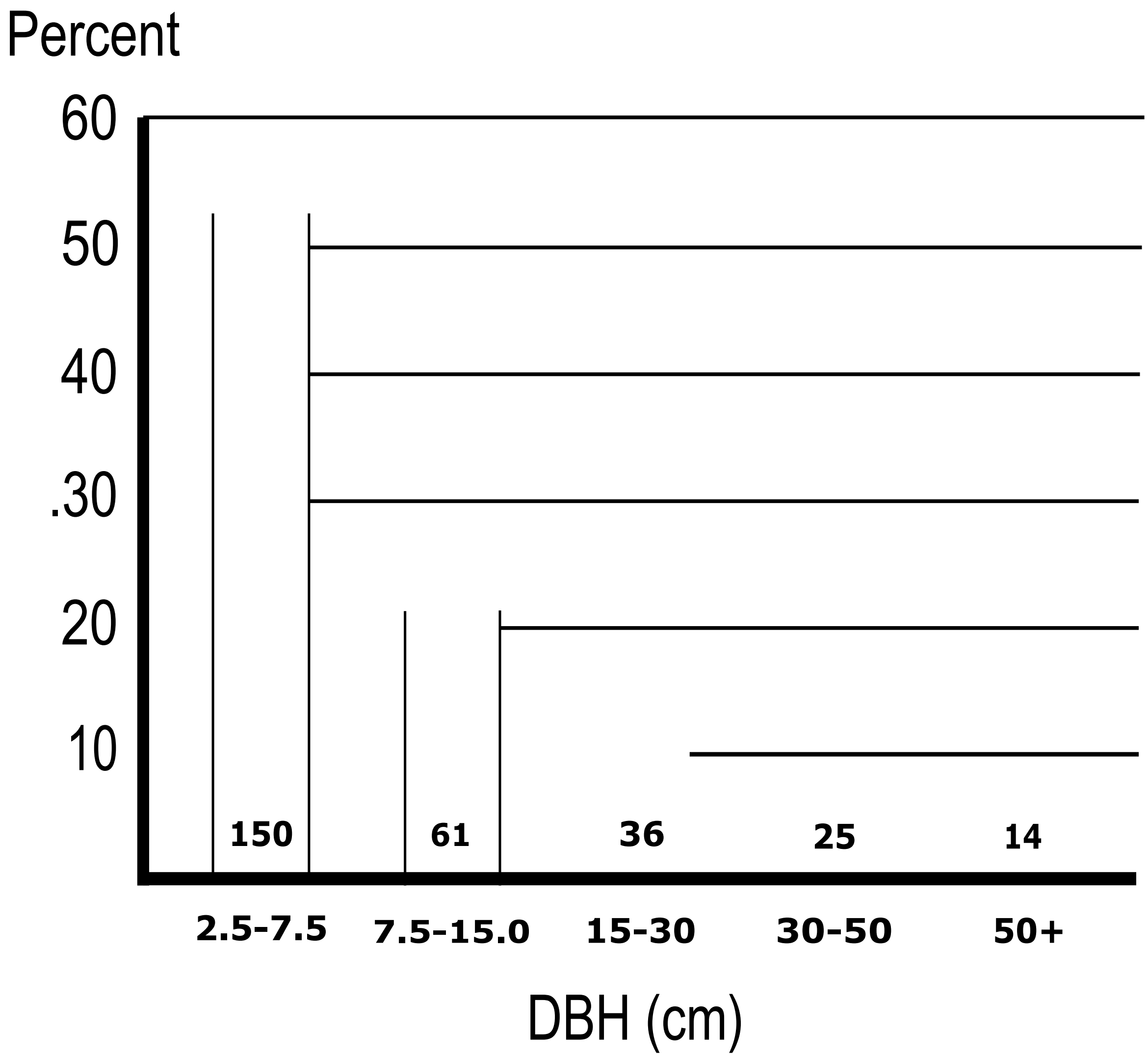

Figure 3. Proportion of trees cut by beaver based on diameter at breast height (DBH) along the Big Sioux River of eastern South Dakota.

Table 10. Comparison of least square means of diameter at breast height (DBH) and distance from water of 9 tree species cut by beaver along the Big Sioux River of eastern South Dakota.

Species	Mean DBH (cm)		Mean Distance from water (m)	
	Uncut	Cut	Uncut	Cut
Green ash	30.3	14.2**	25.7	6.8**
Boxelder	22.8	9.8*	21.4	6.0**
Cottonwood	88.5	0	38.8	0
Peachleaf willow	54.3	18.3**	21.7	6.4**
American plum	5.3	0	23.9	0
Tartarian honeysuckle	3.0	2.5	23.6	1.0
American elm	9.5	7.5	27.9	7.7**
Hawthorn	8.3	9.7	36.4	13.3**
Hackberry	20.5	15.3	20.7	2.8

* Significant at the 0.05 level
** Significant at the 0.01 level

0.01) than the mean DBH (21.7 cm) for uncut trees. Trees cut by beaver were significantly larger ($p < 0.01$) in grazed areas than ungrazed areas.

The mean distance from water of cut trees (6.9 m) was significantly less ($p < 0.01$) than for uncut trees (25.5 m). Beaver selected to cut trees in close proximity to water (Fig. 4) when all species were combined and within each species except honeysuckle and hackberry (Table 10). There was no significant difference ($p = 0.29$) between the mean distance from water of trees cut in grazed areas (3.3 m) than in ungrazed areas (7.5 m). There was a significant difference ($p < 0.01$) between the mean distance from water of uncut trees (26.6 m) and cut trees (3.3 m) in grazed areas and between uncut trees (25.6 m) and cut trees in ungrazed areas (7.5 m).

Of the 286 trees that were damaged by beaver, 138 (48%) were killed and 148 (52%) were not killed by this activity (Table 11). On 82 trees which were cut, the trunk was not killed and resprouted allowing regrowth, while 66 trees remained standing and alive after the damage inflicted by beaver.

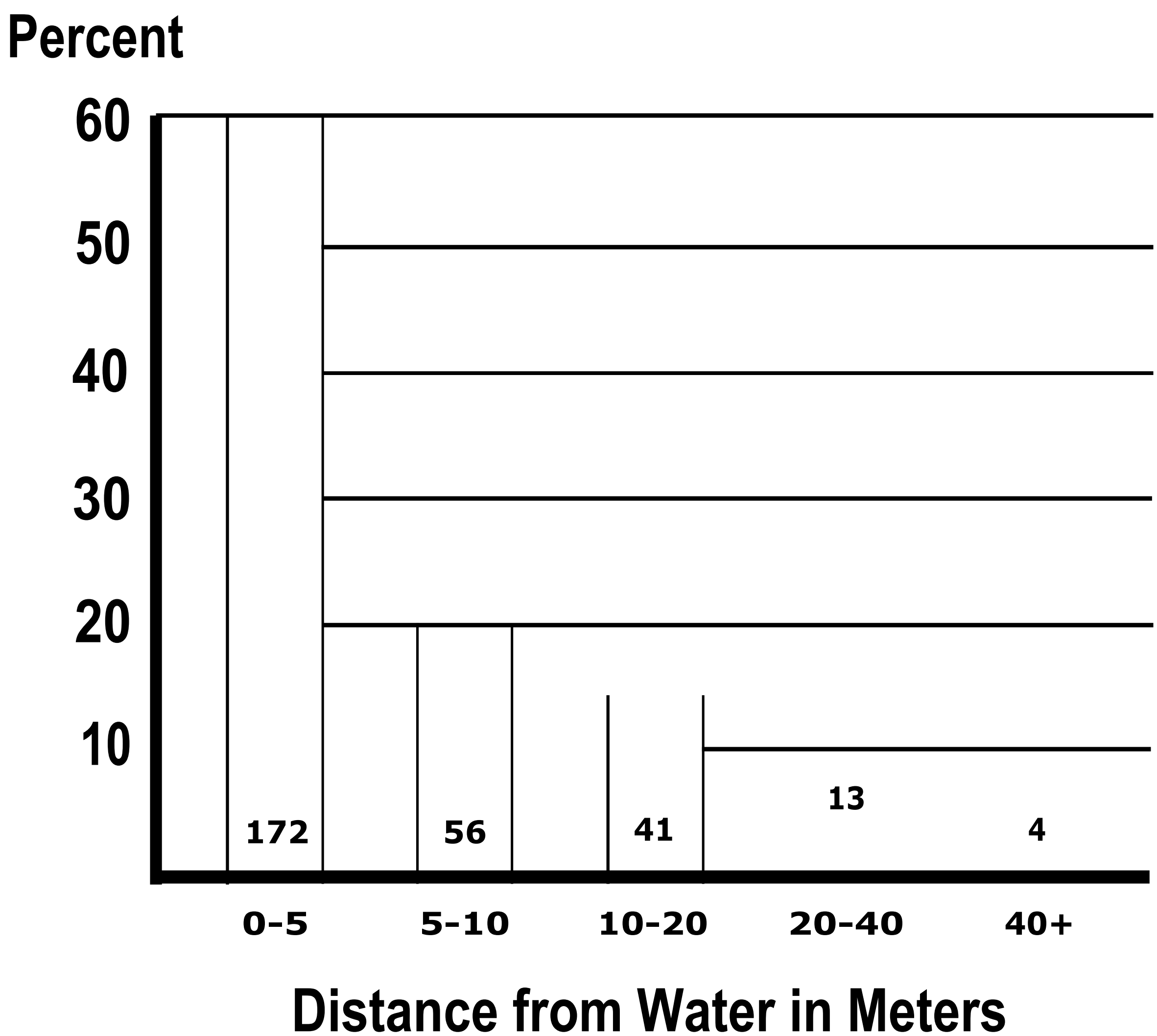

Figure 4. Proportion of trees cut by beaver based on distance of the tree from water along the Big Sioux River of eastern South Dakota.

Table 11. Comparison of specific conditions of tree species and stems after beaver damage along the Big Sioux River in eastern South Dakota during summer 1986.

Species	Dead	Damaged but standing	Cut with regrowth	Total
Green ash	90	45	62	197
Boxelder	12	4	2	18
Peachleaf willow	13	8	9	30
American elm	16	2	8	26
Hawthorn	6	3	1	10
Hackberry	1	3	0	4
American plum	0	1	0	1
Total	138	66	82	286

DISCUSSION

The effect of beaver damage on riparian habitat can often be difficult to assess. Detrimental effects of beaver activity on planted hardwood seedlings have been documented especially in the southeast (Krinard and Johnson 1981). Along a natural riverine system, however, beaver activity can be viewed as beneficial to the ecosystem. Beaver activity has been shown to have beneficial impact on fisheries in warm-water streams, such as the Big Sioux River, by slowing currents and increasing stream fertility (Hanson and Campbell 1963). The damming of small feeder streams creates productive ponds which can be important in providing habitat for wildlife, especially waterfowl (Beard 1953, Henderson 1960, Knudsen 1962).

In order to accurately assess the impact of beaver on riparian habitat, a basic concept of what the habitat consists of is necessary. The effects of livestock grazing, which has caused a dichotomy in habitat conditions along the Big Sioux River, can influence beaver activity (Munther 1981). Areas unaltered by grazing have an abundance of small trees and stems of common species which are important to beaver populations (Novakowski 1967, Northcott 1971, Jenkins 1975, Jenkins 1979, Pinkowski 1983). Grazed areas have a few large trees and almost no small trees or stems available for beaver use.

Beaver generally depend on woody plants for food during fall and winter, while adding herbaceous species to their diet in spring and summer (Northcott 1971, Svendson 1980, Roberts and Arner 1984). Willow stems are an important food item for many beaver populations (Hammond 1943, Swenson and Knapp 1980). Dense thickets of sandbar willows, with their characteristic stem-like growth along the Big Sioux River in ungrazed areas, provided an easily accessible food source and building material. Domestic livestock eliminate this food source, so that beaver living adjacent to grazed areas must select alternate forage species.

My study indicated that more beaver activity occurred in ungrazed areas. This was due to the greater availability of sandbar willow stems and the higher density of small diameter, preferred tree species. Due to the availability of only large diameter trees, little beaver activity occurred in grazed areas. The limited cutting of large trees in grazed areas probably was due to availability rather than selection, as larger trees are generally cut only after small ones are used (Johnson 1983).

Small diameter trees near waterways were easier to cut and transport to lodge sites. In ungrazed areas, beaver had an abundance of trees available close to shore and could be selective, using small diameter trees first. Beaver living in grazed areas apparently used whatever size tree was available in close proximity to water. In most cases, beaver did not travel far from water to cut trees in any habitat. Beaver generally limit cutting away from water (Belovsky 1984).

Aspen *(Populus tremuloides)*, where present, is the preferred tree species of beaver (Hall 1960, Brenner 1962, Northcott 1971), but beavers often thrive where aspen are unavailable (Chabreck 1958, Nixon and Ely 1969). The utilization of green ash has been documented in other studies (Crawford et al. 1976, Pinkowski 1983). Green ash was the preferred tree species by beaver along the Big Sioux River. Peachleaf willow trees were used in proportion to their availability, but comprised a majority of the large trees cut. Once felled, beaver tended to use only the branches of these large trees.

Small diameter boxelder trees close to shore were common but seldom cut in ungrazed areas, while in grazed areas few boxelder trees were available. Avoidance of boxelder may have been due to taste or to texture of the wood. Hawthorn may have been avoided due to the presence of long, pointed spines on their stems.

In this study, less than half of the trees cut by beaver died. Some damaged trees remained alive and standing, while in many cases felled trees and stems resprouted, creating dense woody habitat. Hall (1960) showed that the quantity of willow removed at colony sites by beaver in California was almost totally replaced each year by rapid regrowth. In Oregon, willows used by beaver were able to maintain high growth rates and increased basal diameter similar to the rates of unused trees (Kindschy **1985)**. Krinard and Johnson (1981) reported that nearly all hardwoods cut by beaver in Mississippi sprouted back with little growth loss. Periodic fluctuations of beaver populations likely allow recovery of vigor in willow and similar riparian species (Kindschy 1985).

Beaver damage appears to have been greater in ungrazed areas where approximately 7% of the trees had been killed. However, the majority of tree cutting occurred on small diameter ash trees, which can regenerate rapidly. There is little damage to existing large trees, or any trees over 10 m from water. Instances of localized damage close to shore are possible, but were rarely seen.

Damage incurred to trees in grazed habitat may be greater even though these areas are seldom used by beaver. While only about 3% of the trees have been killed by beaver, almost all were large, mature trees and were not being replaced by regeneration due to effects of livestock.

Natural and prolonged utilization of habitat by beaver did not appear to be responsible for the reduction, deterioration, and loss of riparian tree species. Other factors, including continual cropping and trampling of regrowth by livestock during the growing season, were involved in limiting the riparian community along the Big Sioux River.

MANAGEMENT IMPLICATIONS

Although findings from my research indicate that beaver use grazed habitats along the Big Sioux River, ungrazed areas were selected for and are most important to beaver populations. Rather than travel farther inland to cut large trees, beaver in grazed areas may have moved to ungrazed areas where there was a greater abundance of stems and preferred trees. Establishment of areas that will remain free of livestock grazing would benefit beaver populations.

Due to availability of suitable habitat, ungrazed areas along the Big Sioux River appear to be capable of sustaining a larger population of beaver than grazed areas. The habitat is sufficient to support beaver populations at current levels with few negative effects. The fact that beaver are being selective for trees by species, size, and distance from water indicates that the habitat is capable of supporting the current population, as a population running short of resources could ill afford to be selective.

An increase in beaver populations in a reduced ungrazed environment could cause localized damage. Increased cutting of larger trees as well as trees farther from water may occur. If livestock begin using areas now ungrazed, it may cause beaver to move to ungrazed areas, increasing damage potential in those areas.

Due to increasing populations of beaver in recent years, hunting of beaver during spring flooding has increased, allowing a larger harvest along the Big Sioux River. This activity as well as an increase in fur prices could reduce the population which in turn would reduce the impact of beaver on the habitat.

A return of suitable ungrazed habitat could help to distribute the existing beaver population over a greater area. Restriction of livestock grazing within a predetermined distance from habitat along the river or old river channels would allow regeneration of the forest in areas now grazed. Beaver only influence areas of forest near the river while cattle grazing affects the forest from streamside to its outer edge. Many species of birds and wildlife would benefit from the increased habitat and loss of topsoil to erosion would be curbed.

Chapter 2

LODGE SITE SELECTION BY BEAVER ALONG THE BIG SIOUX RIVER

The fundamental unit of a beaver population is the colony, which typically consists of 4 to 8 related individuals, oftentimes an adult pair and their offspring (Bradt 1938, Bergurud and Miller 1977). Beavers, like many rodents, build intricate burrows for denning sites. However, beavers have the unique ability to cut trees, which enables a colony to build elaborate lodges made of sticks and mud along waterways.

Lodge sites are often traditional, being used by a family unit for several years. Beavers generally disperse at 2 years of age (Bradt 1938, Aleksiuk 1968) and may mate to form new colonies. While searching for lodge sites, dispersing beaver avoid territories marked by scent mounds of other colonies (Aleksiuk 1968). Lodge site selection is also influenced by population levels (Bradt 1938), and habitat quality (Slough and Sadleir 1977). Physical factors such as water conditions, bank configuration, and vegetative composition directly adjacent to shore may also influence lodge site selection.

The purpose of this investigation was to determine factors beaver may use in selecting an adequate lodge site. Data from this research may be important in helping wildlife personnel in efforts to identify, manage, and in some cases preserve existing beaver habitat.

METHODS

Beaver lodges in the study area were located by traveling in a boat along approximately 40 km of the Big Sioux River. Only those lodges which had evidence of recent beaver activity such as new wood cuttings or fresh scent mounds were included in the sample. In 1986, 33 active lodges were found in the study area. All but 1 of the active lodges were present in 1985. Lodges located in grazed and ungrazed areas were paired with a control site in the same habitat type using a method similar to that used for selecting vegetation quadrats (Chapter 1).

Due to the variable flow rate and volume of the Big Sioux River, an effort was made to collect lodge site data during a period when the river was at a stabilized level. Beavers generally select lodge sites when there is little fluctuation in water levels such as during late summer along the Big Sioux River. Therefore, to avoid unusual variability due to rising or falling water levels, and to best approximate the conditions when beavers select lodge sites, all measurements were taken during August, 1986.

Vegetative characteristics selected as a basis for comparison between beaver lodge sites and control sites were overstory and understory cover density. Both horizontal and vertical cover may be important in providing concealment of the lodge as well as offering a nearby food source. During hot summer months, overhead cover can decrease direct sunlight penetration. Understory vegetation stabilizes the bank surrounding the lodge and reduces bank erosion.

To determine overhead cover, a spherical densiometer (Lemmon 1957) was used. Readings were taken a distance of 3 m from the lodge or the center of the control site in 3 directions. One reading was taken perpendicular to the river. Two readings were taken parallel to the river, 1 on the upstream side and 1 on the downstream side of the lodge or control site center.

Understory cover density was measured at both lodge sites and random sites using a vegetation profile board similar to that used by Nudds (1977). The 1.8 m board was 15 cm wide and divided lengthwise into 6 levels, with each 30 cm in height. Levels were divided into 20 equal blocks with each corresponding to 5% cover for that level. Horizontal cover was recorded as the percent of each level blocked by vegetation. Six readings were taken, 3 from 10 m and 3 from 15 m away from lodges or control sites. Readings were taken in the same directions used for measuring overstory. The readings of the bottom 3 levels were averaged at each distance to create 2 variables referred to as Nuddsl and Nudds5l. Similarly, the readings of the top 3 levels were averaged to create variables Nuddsl2 and Nudds52.

The width of the river was measured at both site types. Stream width was defined as the horizontal distance from shore to shore over the stream channel and bank that was covered by water (Platts et al. 1983) and was measured to the nearest decimeter. The water depth was measured 1 m from shore and rounded to the nearest centimeter at lodges or control sites. A clinometer was used to measure slope, the angle formed by the downward sloping bank as it meets the horizontal stream bottom (Platts et al. 1983). Slope was measured along the river bank directly in contact with a lodge or control sites.

Data obtained by vegetation sampling and physical measurements (Table 12) were analyzed using stepwise discriminant analysis. Means of individual variables at lodge sites were compared to those at random sites using a t-test. A chi square goodness of fit test was used to determine if grazed or ungrazed habitat was used in a significantly greater proportion (p (0.05) more than its availability. If there was a significant difference, confidence intervals were constructed around the proportion of observed use of the habitat type to determine selection or avoidance (Neu et al. 1974, Byers and Steinhorst 1984).

RESULTS

The 33 lodge sites and non-lodge sites exhibited high variabililty (Appendix 2). Analysis of vegetation variables indicated that canopy cover as well as all 4 understory

Table 12. Variables used in vegetation and physical analyses between lodge sites and non-lodge sites along the Big Sioux River in eastern South Dakota.

Variable	Explanation
SLOPE	Slope in degrees of the river bank
WIDTHM	Width in meters of the river
DEPTHCM	Depth in centimeters of the river measured 1 meter from the bank
CANOPY1	average of 3 densiometer readings
NUDDS1	average of lower 3 sections of the 3 Nudds board readings from 10m
NUDDS2	average of upper 3 sections of the 3 Nudds board readings from 10m
NUDOS51	average of lower 3 sections of the 3 Nudds board readings from 15m
NUDDS52	average of upper 3 sections of the 3 Nudds board readings from 15m

cover measurements were significantly greater ($p < 0.05$) at lodge sites than at non-sites (Table 13). Analysis of physical variables showed that both riverbank slope and water depth were significantly greater ($p < 0.01$) at lodge sites than at random sites, while there was no significant difference in stream width.

Stepwise discriminant analysis of all habitat variables suggested that slope of the riverbank and understory cover density between 0.9 m and 1.8 m (read from 10 m) were significant discriminating variables which accounted for 51% of the variation between site types. Using the discriminating ability of these 2 variables, 79% of the lodge sites and 88% of the non-lodge sites were correctly classified. Although larger mean values at lodge sites than at non-lodge sites for the other variables appeared important, stepwise discriminant analysis did not indicate a substantial discriminating value using these variables.

Chi square tests for habitat use indicated that there was a significant difference ($p < 0.05$) between the number of lodges found in grazed areas and ungrazed areas and the number expected if beavers were randomly selecting lodge sites (Table 14). Selection/avoidance analysis determined that ungrazed areas were being selected ($p < 0.05$) by beaver for lodge sites, while grazed areas were not selected (Table 14).

Table 13. Comparison of means of variables used in analysis of 33 beaver lodge sites and an equal number of random sites along the Big Sioux River.

Variable	Sitetype	Mean	S. E.	T-value	df
Nudds1	Lodge	89.3	1.7	3.13**	64
	Random	78.3	3.0		
Nudds2	Lodge	53.0	4.8	4.16**	64
	Random	28.2	3.5		
Nudds51	Lodge	94.6	1.3	2.70**	64
	Random	86.0	2.9		
Nudds52	Lodge	68.0	4.3	3.13**	64
	Random	47.8	4.8		
Canopy1	Lodge	41.2	4.3	2.52*	64
	Random	26.4	4.0		
Depthcm	Lodge	75.5	4.8	4.00**	64
	Random	49.4	4.5		
Widthm	Lodge	19.9	0.9	0.06	64
	Random	20.0	0.9		
Slope	Lodge	40.7	2.1	5.32**	64
	Random	26.7	1.6		

* Significant at the 0.05 level
** Significant at the 0.01 level

Table 14. Selection or avoidance of land use types by beaver for lodge sites along the Big Sioux River in eastern South Dakota in 1986.

Land use	Proportion of study area	Proportion Expected	Proportion Observed	95% CI on proportion observed
Grazed	.60	19.8	6(.182)a	.034 < P1 < .330
Ungrazed	.40	13.2	27(.818)s	.670 < P2 < .966

Chi-sq value = 23.9** significant at 0.01 level

a = avoidance (proportion of study area > upper confidence limit);

s = selection (proportion of study area < lower confidence limit)

DISCUSSION

The Big Sioux River has a stream gradient that is ideally suited for beaver habitation (Retzer et al. 1956, Rutherford 1964). Although portions of the Big Sioux River forest still provide excellent beaver habitat, land use changes have affected beaver distribution and, therefore, lodge site selection.

Preference of ungrazed areas for lodge sites by beaver reflects the quality of habitat available. Dense thickets of willow stems, abundant small trees, and a variety of aquatic plants provided a diverse and reliable year-round food source. Ungrazed areas contain an abundance of building materials which were easily accessible to beaver.

Munther (1981) stated that heavy livestock grazing can speed up elimination of the food supply available to beaver and hinder colonization. Grazed sections, with few stems and small trees present, usually lack appropriate building materials and sufficient food supplies. Large trees, which were the only available resource for beaver, require much effort to cut, and are usually cut only when small trees are unavailable (Johnson 1983). When large diameter trees were felled, only the branches which beaver could carry were transported to lodge sites for use.

Along the Big Sioux River, beaver selected steep banks for lodge sites. Bank lodges are more common than lodges surrounded by water along the Big Sioux River. Lodges generally have 2 or more underwater entrances (Grinnell et. al. 1937) and areas with a steep bank usually were adjacent to water with sufficient depth to conceal entrances to the lodge. Steep banks also allowed beavers to burrow fairly large chambers above water level. Understory cover and overhead cover densities were higher at lodge sites than at random sites and trees in close proximity to lodges were usually left uncut. This indicated that overhead concealment of lodges as well as concealment at ground level may have been important selection criteria for beaver.

Physical conditions along the river in grazed areas did not differ greatly from those in ungrazed areas. Beaver have the ability to alter the physical conditions near lodge sites for their benefit through the use of dams or canals. Avoidance of grazed areas for lodge sites may have been influenced more by the lack of sufficient resources for building and food than by physical factors.

Management Implications

Practical management for beaver involves (1) protection of the physical environment from land use practices which degrade the land base for beaver production, and (2) management of the food supply (Slough and Sadleir 1977). Munther (1981) stated that livestock can rapidly modify riparian vegetation by reducing forage, wildlife and fisheries habitat, and watershed values, while beaver are responsible for the productivity of riparian areas.

Since beaver along the Big Sioux select for ungrazed areas with a steep bank and dense cover, elimination of livestock grazing would likely provide for more desirable lodge sites. This would enhance beaver distribution and production as well as cause a return to the benefits of a natural riparian ecosystem.

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Appendix 1. Means and standard errors of DBH (diameter at breast height) for 9 tree species sampled along the Big Sioux River during 1986 in 3 habitat classifications.

Species MEAN DBH (cm) S.E.	Grazed	Ungrazed	Farmed
Green ash	40.8a 1.4	22.6b 0.8	24.9b 9.9
Boxelder	38.3a 2.6	20.4b 1.0	22.4b 5.4
Cottonwood	85.7a 26.2	91.5a 7.1	0 0
Peach-Leaf Willow	52.0a 3.0	48.8a 3.8	79.6a 25.0
Tartarian honeysuckle	6.7a 1.5	5.1a 0.7	0 0
American plum	2.5a 0.0	3.2a 0.3	2.5a 0.0
American elm	12.1a 1.7	8.7b 0.6	7.6c 1.3
Hawthorne	8.7a 1.6	8.4a 0.6	0 0
Hackberry	31.0a 5.7	16.6b 3.2	0 0

a = Significantly different ($p < 0.05$) than b
b = Significantly different ($p < 0.05$) than a
c = Not Significantly different ($p < 0.05$) than a or b

Appendix 2. Means, ranges and standard errors of all variables used in vegetation and physical analyses between beaver lodge sites and non-lodge sites along the Big Sioux River in Eastern South Dakota.

	Lodges			Non-lodges		
Variable	Mean	Range	S.E.	Mean	Range	S.E.
Riverbank slope	40.7	10-71	2.1	26.7	9-41	1.6
Width of river (m)	19.9	9-35	0.9	20.0	7-28	0.9
Depth of river (cm)	75.6	30-145	4.8	49.4	23-169	4.4
Overstory cover	41.2	0-98	4.3	26.4	0-88	4.0
Understory(10m) cover(<0.9m)	89.3	67-99	1.7	78.3	36-99	3.0
Understory(10m) cover.9-1.8m)	53.0	6-99	4.8	28.1	0-67	3.5
Understory(15m) cover(<.9m)	94.6	68-99	1.3	86.0	38-99	2.9
Understory(15m) coverc)9-1.8m)	68.0	13-99	4.3	47.8	0-88	4.8