Riparian Areas, Biodiversity & Livestock Grazing

A Summary and Analysis of Research in Alberta and Saskatchewan

Prepared for Canadian Wildlife Service, Environment Canada

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March 2001

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Acknowledgements

This report was a cooperative effort and I would like to thank all those who assisted: Brenda Dale, Al Smith, Barry Adams, Cleve Wershler and Andy Hurly provided data and reports. Lorne Fitch and Ron Bennett provided insight and direction for the project. Andy Hurly provided input on the meta-analysis. Feedback on the draft report was given by Ron Bennett, Brenda Dale, Al Smith, Garry Trottier and Lorne Fitch. Cows and Fish program staff conducted the riparian health inventories used in this report and Norine Ambrose provided additional information on inventory methods.

Cover photos by the author.

1. Executive Summary

Riparian areas are important to a variety of wildlife and plants and landuse practices can influence this biodiversity. In prairie Canada, a major landuse of riparian areas is livestock grazing. Presented here is a summary of six studies, conducted in Alberta and western Saskatchewan, that investigated the influence of grazing on bird communities. Also included are the results of a pilot invertebrate study and a vegetation study. All of the avian studies found some grazing effect on bird communities, primarily a reduction of native species abundance and richness.

Riparian health assessments were available for three of the study areas. One study area had a sufficient sample size to allow statistical comparisons of health assessment variables and bird community variables. A significant positive relationship was found between measures of the shrub community (shrub volume and number of shrub species) and avian abundance.

A meta-analysis was performed on the combined data, which indicated a general negative effect of grazing on species richness and avian abundance across a broad geographic area in Alberta and western Saskatchewan.

The response of individual bird species to grazing was examined in each of the six studies. Sixteen common riparian species decreased with grazing in the majority of the studies. Species that generally decreased with grazing were: least flycatcher, gray catbird, cedar waxwing, yellow warbler, common yellowthroat, red-winged blackbird and American goldfinch.

Results of the Alberta and Saskatchewan studies parallel similar research conducted in other parts of North America, where intensive grazing negatively influenced bird community evenness, richness and abundance.

Eight dominant messages emerged from the combined results of the six studies. The messages are summarized below:

- High intensities of grazing result in reductions in breeding bird abundance.
- High intensities of grazing result in reductions in breeding bird species richness.
- There are several potential indicator bird species that appear to be sensitive to grazing.
- High intensity grazing results in reductions in fall bird abundance and species richness
- High intensity grazing results in increases in European starlings, a non-native species.
- Although there may be similarities between riparian systems, each riparian system is unique.
- Ungrazed riparian areas are uncommon and therefore extremely important as benchmark sites.
- Appropriate riparian grazing thresholds have yet to be defined.

A number of recommendations are made. Firstly, six primary areas where additional research is required are identified. Secondly, three stewardship-based recommendations are made relating to grazing management and riparian health. Two supplementary recommendations are made, pertaining to publishing of riparian studies and protecting riparian benchmark sites. Lastly, several methodological suggestions are made for conducting research into grazing effects in riparian areas.

2. Introduction

Various studies have demonstrated relationships between livestock grazing intensity and biodiversity, primarily bird communities. The majority of this work has been undertaken in grasslands (Kantrud 1981, Bock et al. 1984, Ivey 1994, Bock and Bock 1999), however, some work has been conducted in riparian areas (Mosconi and Hutto 1981, Taylor 1986, Schulz and Leininger 1990, Ammon and Stacey 1997, Dobkin et al. 1998). Generally in riparian areas an indirect effect is seen; birds are not responding to the presence of livestock, but to changes in the riparian vegetation resulting from livestock grazing. Where cattle are present in riparian areas during the breeding season there can be direct effects on productivity of ground nesters as a result of trampling (B. Dale pers. comm.).

Cattle tend to concentrate in riparian areas because of the attraction of water, shade and lush vegetation. Livestock grazing can affect riparian habitats in several ways: direct browsing of trees and shrubs has the potential to reduce or eliminate components of the vegetation community; trampling of the soil and streambanks can change vegetation composition and alter bank and stream profiles; and in some extreme cases, livestock grazing can effectively eradicate the riparian zone by reducing the water table and widening channels (Platts, 1991). Grazing also has been shown to reduce or eliminate the regeneration of forests by reducing numbers of tree seedlings (Glinski, 1977).

Riparian areas are important to birds and other wildlife in all seasons. The highest densities and diversities of breeding birds in continental North America have been recorded in riparian habitats (Carothers and Johnson 1974, Ohmart and Anderson 1986, Saunders 1988). The contribution of riparian areas to avian diversity is disproportionate to other western habitats (Saab et al., 1995). Thus, riparian habitats are critical to the conservation of many western birds, especially neotropical songbirds, the majority of which rely on riparian habitats for breeding or as stop-over sites while migrating (Saab et al., 1995). In Alberta and Saskatchewan, several studies have investigated the influence of grazing on biodiversity in riparian areas along rivers and creeks (Wershler and Smith 1995, Smith 1999, Saunders and Hurly 2000b). Most of these studies have shown similar results to those in the United States, with decreases in breeding bird abundance and diversity with increasing grazing intensity in riparian areas.

The objectives of this study and report are to:

- Compile and summarize what has been found to date in Alberta and Saskatchewan regarding the relationship between biodiversity and livestock grazing in riparian areas.
- Identify common results and generalizations applicable to riparian areas & incorporate the results of riparian health inventories conducted by the Cows and Fish Program*.
- Compare the results of the Alberta and Saskatchewan studies with similar work elsewhere.
- Identify where further work will be beneficial.
- Summarize the dominant messages of value for riparian stewardship programs to ultimately assist in the management of riparian areas.

*The Cows and Fish program is a partnership established in 1992 to foster a better understanding of riparian values and management among livestock producers and communities.

The first part of this report contains a summary of the methods and results from six studies that examined the influence of grazing on riparian birds. Also included are the results of vegetation studies at the Oldman River sites and a pilot study looking at invertebrates. However, birds are the primary focus because they are easier to study than other groups and are considered a good measure of overall biodiversity (Bock and Webb, 1984). Although much of these data have been reported elsewhere, this is the first time that the results of these similar studies have been presented together.

The second part of the report contains new analyses using data from the original studies. Firstly, there is an analysis of the relationships between riparian health assessments, collected by the Cows and Fish Program, and riparian bird data. Secondly, a meta-analysis combines all the bird studies to see if there are common trends across all of the studies. Finally, individual species' response to livestock grazing in riparian areas is examined for common patterns.

The third part of the report relates the findings of the Alberta and Saskatchewan studies to similar studies conducted in North America, highlights dominant themes and confirmatory results, and makes recommendations for future work.

3. Summary of Existing Studies, Methods and Results

Several studies of the influence of livestock grazing on riparian biodiversity have been undertaken in Alberta and Saskatchewan. Breeding bird populations have been the focus of these, although some have studied birds during the migratory season and one study assessed invertebrate biodiversity. Presented in this section is a summary of these studies.

Four studies in Alberta and one in western Saskatchewan have looked at the influence of livestock grazing on breeding birds in riparian areas (Wershler and Smith 1994, Hurly and Saunders 1998, Dale et al. 1999, Smith 1999, Saunders and Hurly 2000b, Table 1). Two studies have looked at birds during migration seasons (Dale et al 1999, Saunders and Hurly 1999). It should be noted that the Suffield work (Dale et al. 1999) was not conducted for the purpose of assessing the influence of grazing, but as part of an overall avian inventory in the National Wildlife Area. Similarly, the primary intent of the Saskatchewan study was to examine avian diversity along the South Saskatchewan between Estuary and Leader.

Table 1: Investigations of the influence of grazing on riparian birds in Alberta and Saskatchewan included in this summary

Study Drainage	Year/s	Bird data collected	Principle Researcher/s
Pekisko Creek, Alberta	1994 - 1997	Breeding birds	Cleve Wershler
Oldman River, Alberta	1997 - 1999	Breeding birds and fall birds	Liz Saunders and Andy Hurly
South Saskatchewan River, Alberta	1994 - 1996	Breeding birds and migratory (fall and spring) birds	Brenda Dale
South Saskatchewan River, Saskatchewan	1998	Breeding birds	Al Smith
Pothole Creek	2000	Breeding birds	Liz Saunders and Andy Hurly

The study areas cover a broad geographic range in southern Alberta and into western Saskatchewan (Figure 1). A summary of the locations and features of the study sites is given in Table 2. Appendix A gives the coordinates for the two study areas along the South Saskatchewan.

Table 2: Brief Descriptions of Study Areas

Study Drainage	Natural Region	Location	River Type	Vegetation Type
Pekisko Creek, Alberta	Foothills Fescue	Bar U Ranch and vicinity south of Calgary	Meandering foothills creek	*Populus balsamifera* forest with shrub understory such as *Salix spp*., *Elaeganus commutata* and *Symphoricarpos occidentalis*.
Oldman River, Alberta	Grasslands	Fort Macleod and Lethbridge	Wide meandering river	Extensive cottonwood forests (*Populus deltoides, Populus balsamifera and Populus augustifolia*) and shrub understory
South Saskatchewan River, Alberta	Grasslands	Suffield Military Reserve	Wide, somewhat entrenched river	Cottonwood forests, primarily *Populus deltoids,* some Manitoba Maple (*Acer Negundo*) with shrub understory
South Saskatchewan River, Saskatchewan	Grasslands	Estuary - Leader	Wide meandering river	Cottonwood forest (*Populus deltoids*) with understory of shrubs such as *Salix spp.* and *Sheperdia argentea*
Pothole Creek	Grasslands	Magrath Area (south of Lethbridge)	Meandering prairie creek with associated cattail wetlands	A few poplars (*Populus deltoides, Populus balsamifera and Populus augustifolia*), primarily dense shrub communities (e.g. *Salix spp. Elaeganus commutata, Prunus virginiana*)

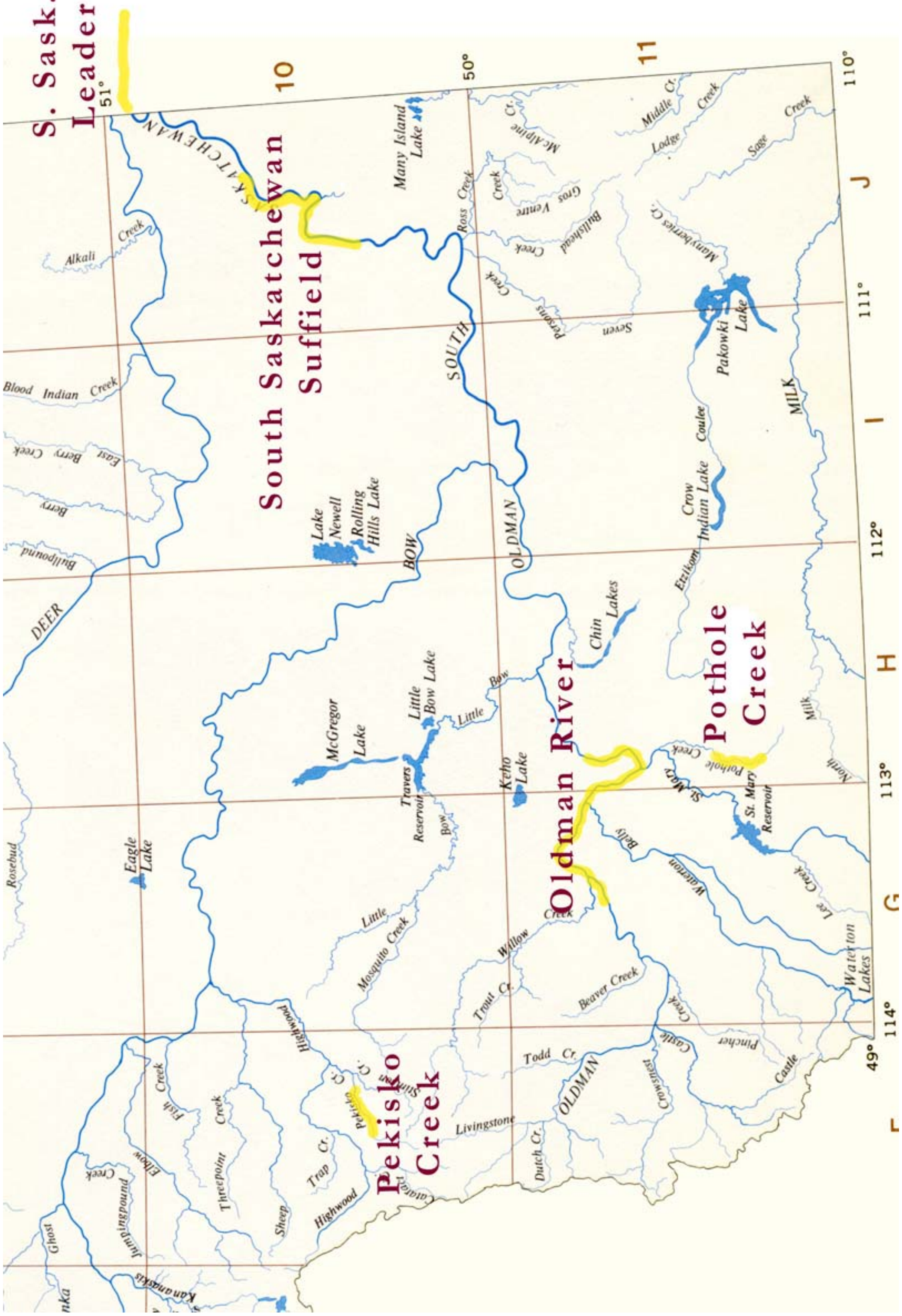


Figure 1: Location of Study Sites included in this Summary

3.1 Methods

3.1.2 Bird Methods

a. Pekisko Creek

This study was conducted by Cleve Wershler for the Cows and Fish Program. Two sites were sampled in this study of breeding birds; one on the Bar-U Ranch, which was heavily used by livestock for decades and one on the McPherson property, which was lightly grazed. Within each site, two 100 meter radius point count circles were established. Breeding birds were recorded for 10 minutes per count circle on two consecutive days in June. The count circles were sampled each year from 1994 to 1997.

b. Oldman River

The breeding bird study was conducted in 1997 for the Cows and Fish Program by Liz Saunders and Andy Hurly. Nine sites were selected in riparian cottonwood stands along the Oldman River between Fort Macleod and Lethbridge, Alberta. Of the nine sites, three were heavily used by cattle, three were moderately used by cattle, and three had not been used by cattle for at least 20 years. Within each of the nine sites, four 50 meter radius sampling circles were established. Breeding birds were surveyed for 15 minutes in each circle using the point-count method. Each site was sampled twice during the breeding season (June). Detailed sampling of the vegetation at all nine sites was carried out.

For the fall birds study in 1998, the same nine sites were used. For three separate sampling periods from August 23rd to September 22nd, each site was walked for one hour in the vicinity of the point count circles used for the breeding bird surveys. All birds heard and seen were counted and care was taken to count each bird only once.

c. South Saskatchewan, Suffield

Surveys of breeding and migrating birds in riparian areas were conducted as part of the Suffield avian inventory work by the Canadian Wildlife Service from 1994 to 1996 (Dale et al. 1999). Walk-through surveys were conducted in four main riparian areas; Sherwood Forest (not grazed for over forty years), Dugway (more than 10 years between grazing events, 3.4 acres per cow, fall grazing), Bull Pen Woods (grazed almost annually, 6.6 acres per cow, fall grazing), and Riverbend Woods (annual grazing, 6.6 acres per cow). Because each riparian area varied in shape and size and the primary objective was to develop a species list, standardized surveys (e.g. point counts) were not conducted. However, the time spent in each area was recorded so that data can be converted into encounter rates for each species. The vegetation community was described as part of a separate inventory (Adams et al. 1997).

d. South Saskatchewan River Leader – Estuary

Conducted in 1998 and 1999 between Estuary and Leader, Saskatchewan, this Canadian Wildlife Service study was led by Al Smith. He surveyed breeding birds at a total of 36 point counts circles, of which, 26 were classified as grazed and 10 were classified as ungrazed. Sites were classified as grazed if they were fenced and showed evidence of grazing such as the presence of cattle, trampling, fresh trails or droppings. Ungrazed sites were unfenced and showed no evidence of cattle use. The count circles were 50 meters in radius. All birds recorded on the count circles were recorded as seen or heard within a 0-5 minute or 5-10 minute time period.

Although detailed vegetation sampling was not done, each site was classified by dominant tree species (plains cottonwood or Manitoba maple) and age of stand (mature or immature). The primary focus of this study was to gain an overview of the avifauna of the area, not to conduct an in-depth assessment of the influence of grazing.

e. Pothole Creek

This study was conducted along Pothole Creek, in the Magrath area, between the Jensen Reservoir and Highway 5. Nine riparian sites along the creek were selected: three heavily grazed sites, three moderately grazed sites and three sites that had been unused by livestock for at least 20 years. Two point count circles, with a radius of 50 meters, were established in each site. Birds were recorded for a 15-minute period twice during the breeding season. The vegetation was not sampled.

3.1.3 Comparison of Methods used in Bird Studies

Although each survey used slightly different methods, they contain many similarities. With the exception of the Suffield study, all of the breeding bird studies employed point count methods. Table 3 summarizes the survey methods.

Table 3: Comparison of Study Methods

Study	Season	Bird Survey Method	Radius	Count time	Number of sites	Number of count circles/site	Number of times sampled
Pekisko Creek	Breeding	Point counts	~100m	10 mins	2	2	2
Oldman River	Breeding	Point counts	50m	15 mins	9	4	2
Oldman River	Fall migration	Walk-throughs	N/A	1 hour	9	N/A	3
South Saskatchewan, AB	Breeding & migration	Walk-throughs	N/A			N/A	
South Saskatchewan, SK	Breeding	Point counts	50m	10 mins	36	1	1
Pothole Creek	Breeding	Point counts	50m	15 mins	9	2	2

There were considerable differences between the studies in the degree of grazing pressure. None of the studies contained quantitative measures of grazing pressure. Grazing pressure is extremely difficult to measure in a way that will allow for comparisons across sites; although it may be possible to quantify grazing in terms of animal units per acre per month, this measure only addresses current grazing intensity and does not account for variations from year to year or for differences in historical grazing pressures. Grazing intensity also varies depending on the total size of the pasture and plant community types present (e.g. a mixture of riparian and upland habitats versus only riparian habitats available to cattle). For this report, I have used the following broad classifications and attempted to fit the grazing intensities of each study into this classification:

Nil: No grazing by livestock for at least 20 years

Light: Cattle have access to the riparian area for only part of the growing season, stocked at low densities

Moderate: Cattle have access to the riparian area for only part of the growing season, stocked at moderate to high densities

High: Cattle have access to the riparian area for all of the growing season, stocked at moderate to high densities.

Table 4 summarizes the grazing comparisons made in the six studies

Table 4: Comparison of Grazing Intensities Assessed in Each Study

Study	Comparison of Grazing Intensities
Pekisko Creek	Light and High
Oldman River Breeding Birds	Nil, Moderate and High
Oldman River Fall Birds	Nil, Moderate and High
South Saskatchewan, Alberta	Nil, Moderate and High
South Saskatchewan, Saskatchewan	Nil and Light
Pothole Creek	Nil, Moderate and High

3.1.4 Invertebrate Methods

In 1999, Saunders and Hurly (unpublished data) conducted a pilot study to investigate whether grazing influenced insect biodiversity and biomass. This study was done at three of the Oldman River sites used in the breeding bird study; one was ungrazed, one moderately grazed and one heavily grazed. Insects were sampled in each of the four count circles employed in the breeding bird counts (12 count circles in total). Metal baking trays were spray painted yellow and filled with a saline solution and a drop of dishwashing detergent. Four trays were placed in a systematic manner in each count circle (16 per site) and left for a 24 hour period. The insects were then collected, the trays re-filled and another 24 hour sample was taken. Two sample periods were used; July 29-31st and August 27-29th, 1999. Insects were sorted and identified to order.

3.1.5 Vegetation Methods

Only one of the bird studies included extensive sampling of the vegetation; the Oldman River work. That study used those data to make inferences about the relationships between bird populations and vegetation composition and structure (Hurly and Saunders 1998). An assessment of tree health was also done at the Oldman River sites. In addition to this, the Cows and Fish program completed riparian health assessments for the following study sites; Pekisko Creek, Pothole Creek and Suffield. A component of this summary project is to look for relationships between the riparian health assessment data and the bird populations (see Section 4.2).

a. Oldman River Vegetation

Vegetation was sampled using eight 2 x 2 meter quadrats systematically placed within each of the bird count circles. Within each plot grasses, shrubs, non-native species and the five most common forb species were identified. The percent cover and average height of forbs and grasses were estimated. Shrub cover was estimated at the following heights; 0.5m, 1m, 2m, 3m, and over 3m. Data were averaged across quadrats and then across circular plots to provide mean vegetation measures for each site.

b. Oldman River Tree Health

To assess whether cottonwood tree health varied with grazing level, a simple tree health index was developed. Trees were rated in one of the following categories; 0 (completely dead), 1 (more dead than live limbs), 2 (half dead limbs, half live limbs), 3(more live than dead limbs) and 4(no dead limbs). Between 200 and 280 trees were assessed at each of the nine sites.

3.2 Results

3.2.1 Bird Results

a. Pekisko Creek (from Wershler and Smith 1995 and unpublished data provided by Cleve Wershler)
This study found that bird abundance and number of species (species richness) were higher in the lightly grazed site (McPherson) compared to the heavily used site (Bar U Ranch). This was the case in each of the four years of data collection (Figure 2).

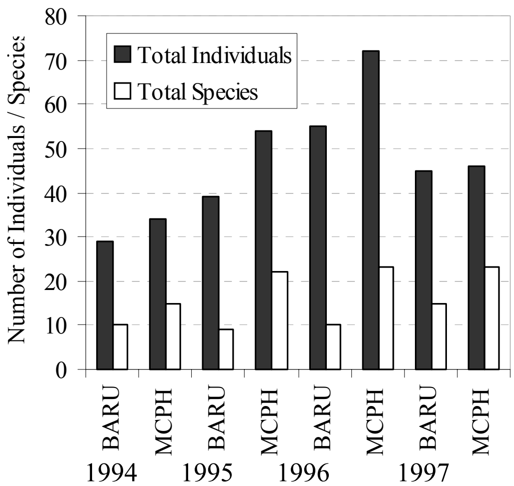


Figure 2: PEKISKO CREEK Bird abundance and species richness was higher in the ungrazed site than the grazed site

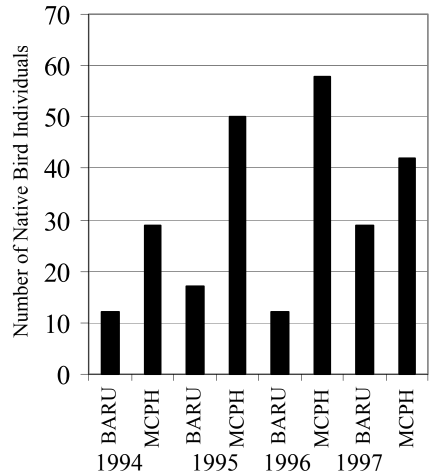


Figure 3: PEKISKO CREEK Abundance of native bird species was considerably higher in the ungrazed site than the grazed site

When the non-native species (starlings and house sparrows) are excluded, the differences are more pronounced (Figure 3). Statistical analyses were not performed on these data by the original author of this study. However, I used paired t-tests to compare the lightly grazed site with the heavily grazed site, using the surveys conducted over time as replicates. The following variables were significantly lower in the heavily grazed site than in the lightly grazed site: species richness ($t=4.94$, $p=0.02$), native bird abundance ($t=3.59$, $p=0.04$), number of aerial insectivores ($t=5.03$, $p=0.02$), number of foliage insectivores ($t=4.99$, $p=0.02$), and the number of ground insectivores ($t=7.67$, $p<0.01$).

b. Oldman River Breeding Birds (from Hurly and Saunders, 1998)
Variations in bird abundance, richness and diversity between grazing levels were tested using one-way ANOVA. The abundance of breeding birds was found to decrease with increased grazing intensity ($F_{2,6}=8.31$, $p=0.02$; Figure 4). Although the differences were not significant, the trend of decreasing species richness with increased grazing was in the predicted direction ($F_{2,6}=2.40$, $p=0.17$; Figure 5).

Bird species diversity indices were calculated using the Shannon-Wiener Index (see Krebs 1989 for an explanation of this index):

$$\text{Diversity Index} = \sum_{I=1}^{N} {}_{i}p_{i}\log_{e}p_{i}$$

Overall, bird species diversity decreased with increased grazing ($F_{2,6}$=4.49, p=0.06, Figure 6). When non-native species were excluded from the analysis, a strong effect between grazing and species diversity was revealed ($F_{2,6}$=11.49, p=0.01).

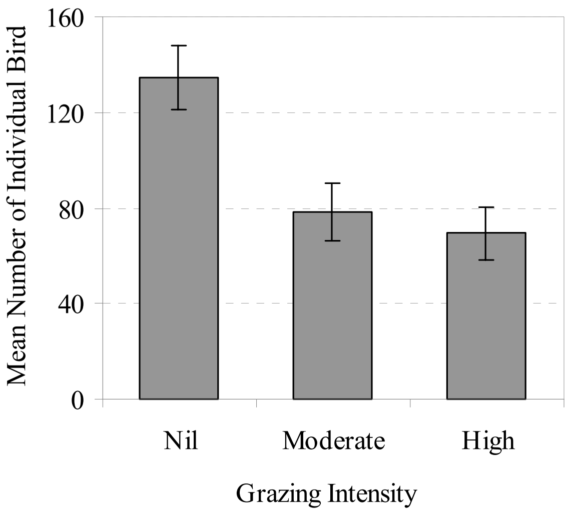


Figure 4: OLDMAN RIVER BREEDING BIRDS Mean bird abundance decreased with increased grazing intensity

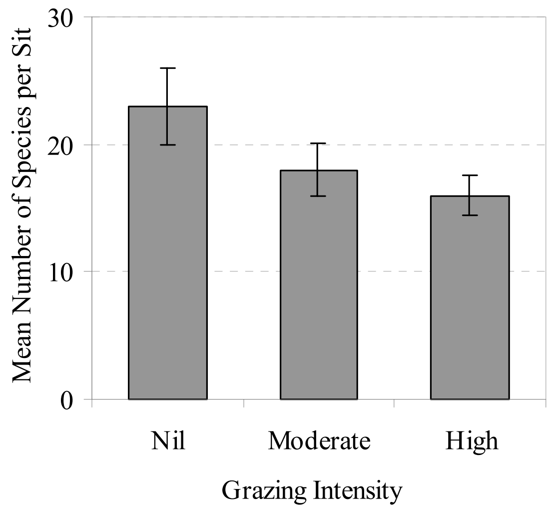


Figure 5: OLDMAN RIVER BREEDING BIRDS Mean species richness decreased with increased grazing intensity

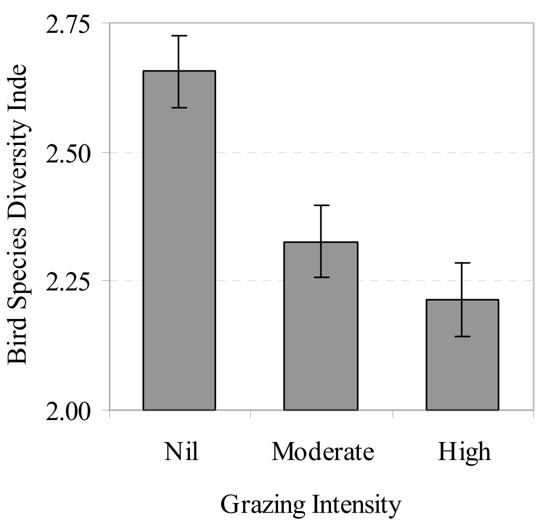


Figure 6: OLDMAN RIVER BREEDING BIRDS
Bird Species Diversity decreased with increased grazing intensity

c. Oldman River Fall Birds (from Saunders and Hurly, 1999)

Page's L-test was used to test the hypothesis that fall bird abundance and richness decreased progressively with increased grazing. Bird abundance decreased with increased grazing intensity (Page's L=42, p=0.01; Figure 7). Heavily used sites had less than half as many birds as the ungrazed sites. Species richness also decreased with grazing level (Page's L=42, p=0.05; Figure 8).

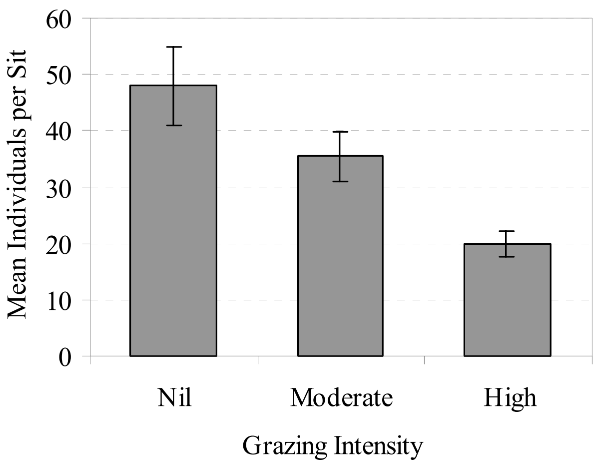


Figure 7: OLDMAN RIVER FALL BIRDS Mean bird abundance decreased with increased grazing intensity

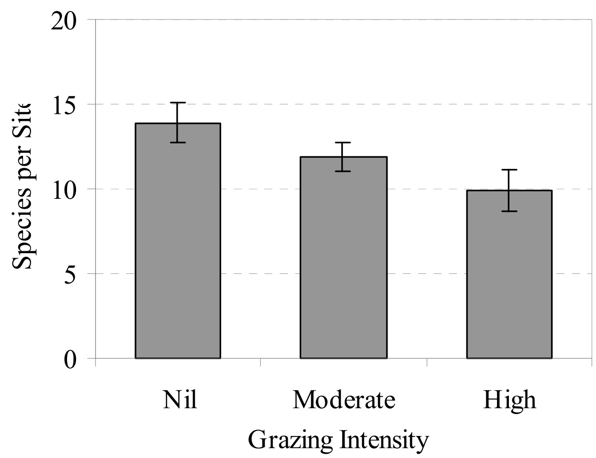


Figure 8: OLDMAN RIVER FALL BIRDS Mean species richness decreased with increased grazing intensity

d. South Saskatchewan – Suffield (from Dale et al., 1999)

Although the influence of grazing on riparian birds was not the focus of this inventory, the study showed that the number of species in riparian woodlands increased with a decrease in the frequency of cattle access and/or a decrease in grazing pressure. The structure and size of the forests varied among the sites, independent of grazing, but Dale et al. suggested grazing decreased local bird diversity. Species most affected by grazing were those that nested in shrubs and old trees. Figure 9 shows the variation of bird encounter rates with grazing. European starlings were very abundant and when they are removed from the data, a trend more similar to the other studies is observed (Figure 10).

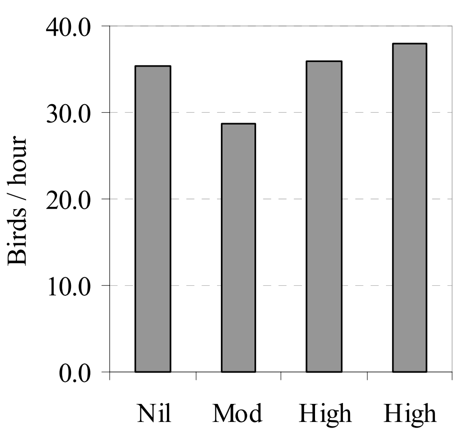


Figure 9: SUFFIELD Variation in bird encounter rates (all species)

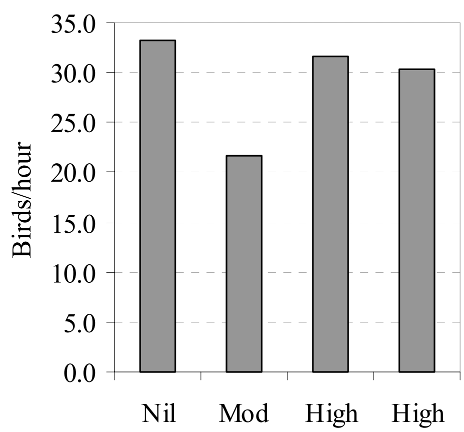


Figure 10: SUFFIELD Variation in bird encounter rates (native species only)

The moderately grazed (Dugway) site appears to be an anomaly in terms of bird abundance. Dugway was ungrazed for at least 10 years, but was then grazed in 1995 at 3.4 acres per animal unit month (Adams et al. 1997). Apparently the cattle strongly favoured this site and removed much of the understory (B. Dale, pers. comm.). It should be noted that encounter rates can be misleading as they are influenced by factors other than bird abundance: variations in the effort required to travel through the habitat, the amount of time spent searching for breeding evidence and time of year (Dale et al. 1999). As species richness deals only with presence and absence, it is perhaps a better measure than encounter rates: Figure 11 shows that species richness decreased with increasing grazing intensities.

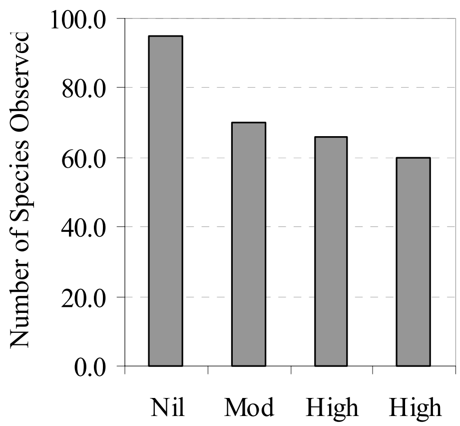


Figure 11: SUFFIELD Variation in Species Richness with Grazing

Note that the following assumptions regarding grazing levels were made based on the information provided; Sherwood Forest = Nil, Dugway = Moderate, Riverbend = High, Bullpen = High.

e. South Saskatchewan Leader – Estuary (from Smith 1999 and unpublished data provided by Al Smith) This study found no overall significant difference in bird abundance or species richness between grazed and ungrazed sites. However there were some species that were significantly more common in the grazed count circles than the ungrazed count circles (American robin, spotted towhee and western meadowlark). Figure 12 shows the comparative abundance of some of the riparian species. The average bird abundance for the grazed sites (12.7) was slightly greater than that for ungrazed sites (11.2), unlike the other studies in this summary, where bird abundance decreased with grazing. This is likely because the grazed sites were fairly lightly grazed and the vegetation structure was not visibly different between the grazed and ungrazed sites (A. Smith pers. comm.).

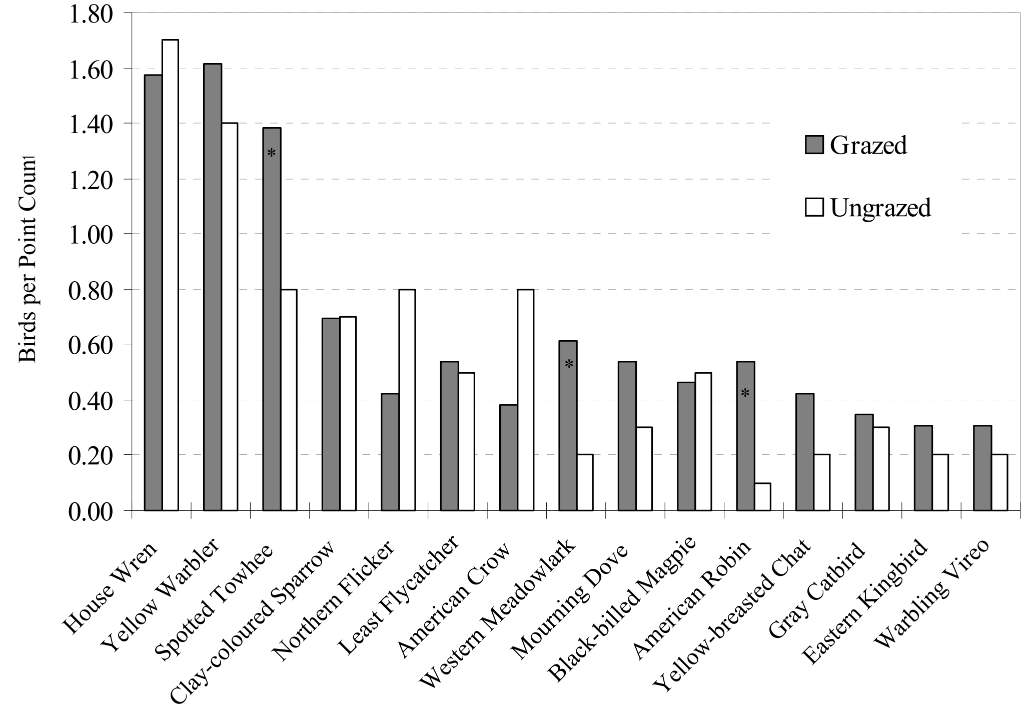


Figure 12: SOUTH SASKATCHEWAN LEADER Comparative abundance of birds on grazed and ungrazed point counts.

f. Pothole Creek (from Saunders and Hurly 2000b)

This study found that as grazing intensity increased, the number of birds and number of species using the riparian zone decreased. Heavily used sites supported about half as many breeding birds as the ungrazed sites, with moderately grazed sites falling in between ($F_{2,6}$=12.23, p<0.01, Figure 13). Species richness also decreased with grazing, although it was not statistically significant ($F_{2,6}$=3.72, p=0.09, Figure 14).

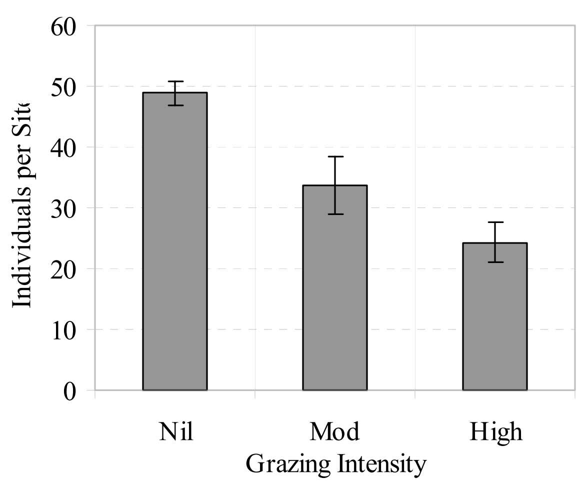


Figure 13: POTHOLE CREEK Breeding bird abundance decreased with increased grazing intensity

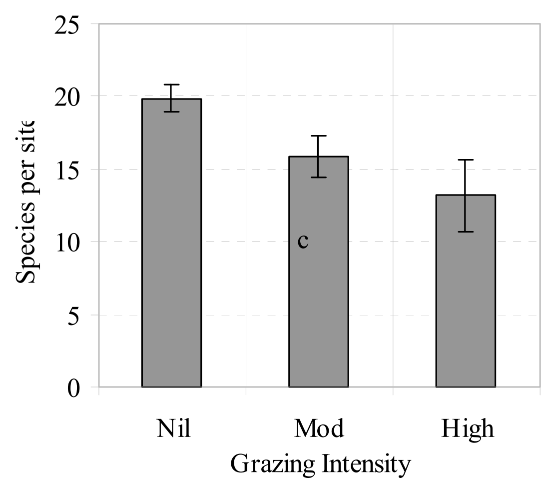


Figure 14: POTHOLE CREEK Species richness decreased with increased grazing intensity

Bird species diversity also decreased with intensity of grazing, but it was not statistically significant because of high variation within the heavily grazed sites ($F_{2,6}$=1.73, p=0.25, Figure 15). Vegetation data was not collected and the reason for this high variation is unclear.

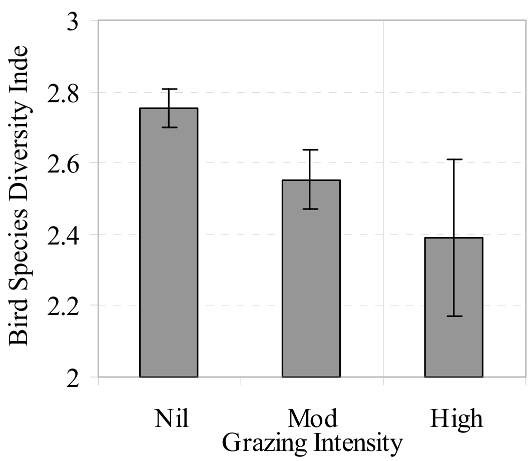


Figure 15: POTHOLE CREEK Bird species diversity decreased with increased grazing intensity

3.2.2 Invertebrates (from unpublished data by Liz Saunders and Andy Hurly)

This pilot project, consisting of one ungrazed site, one moderately grazed site and a heavily grazed site along the Oldman River, yielded 44,630 invertebrates. There was no obvious trend in overall invertebrate abundance (Figure 16). This may have been in part because the insects using the floodplain appeared to be highly influenced by the surrounding habitat. For example, the moderately used site contained large numbers of canola beetles (making up most of the coleoptra abundance in the moderately grazed site); which is explained by the fact that there was a canola field nearby. The sampling method also probably influenced the results. It is likely that the trays used to collect invertebrates attracted lower numbers in the ungrazed sites because they were less visible to insects (they were often hidden under dense shrub cover). This is possibly why orders of insects that were attracted by sight to the trays tended to be present in higher numbers in the grazed sites (e.g. homoptera (aphids, leaf-hoppers) and thysanoptera (thrips). Resources did not allow for identifying invertebrates to the family level, which may have indicated more specific grazing effects.

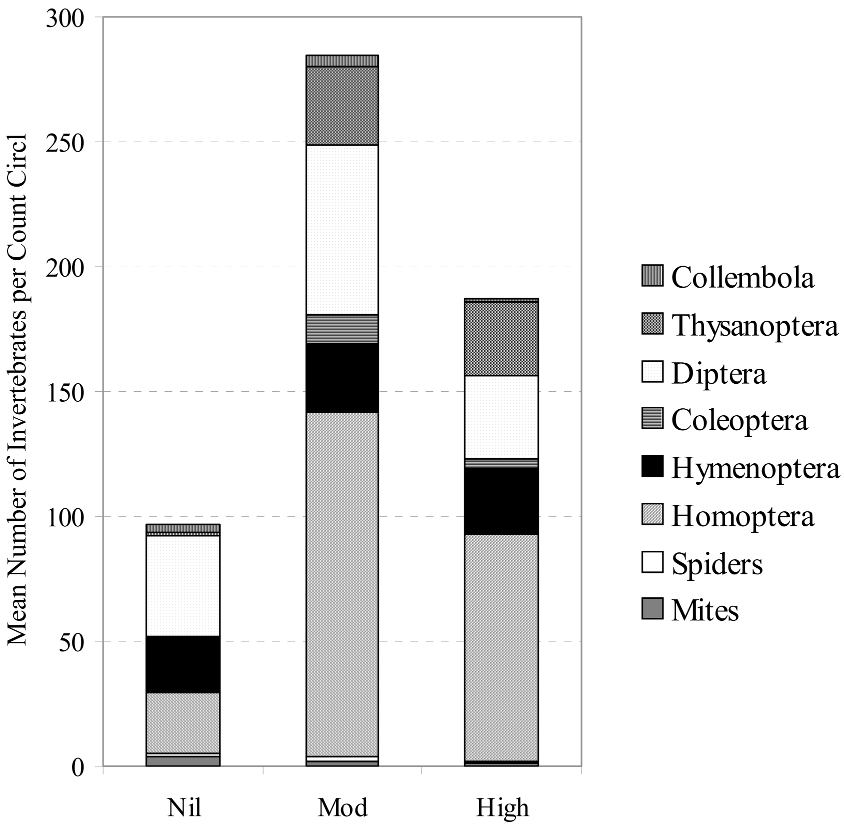


Figure 16: OLDMAN RIVER INVERTEBRATES Variation in mean number of invertebrates in each site by order (only orders represented by more than one individual are shown here).

For species that accidentally encounter the trays rather than being visually attracted, there is a clearer pattern. For example, the number of spiders and mites decreased with increase in grazing level (Figure 17).

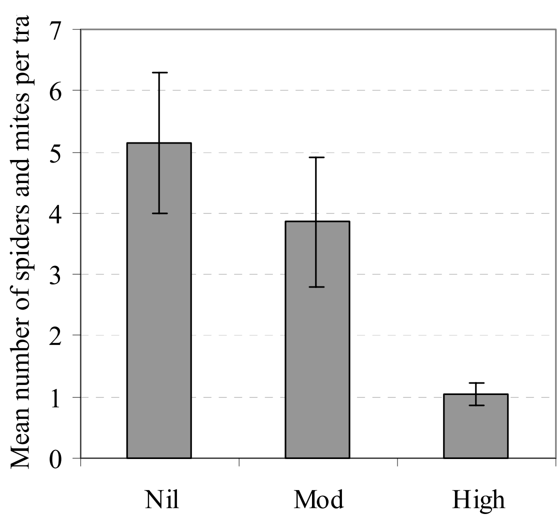


Figure 17: OLDMAN RIVER INVERTEBRATES Mean number of spiders and mites decreased with increasing grazing intensity

When invertebrate order diversity was calculated (using the Shannon-Weiner index), a statistically significant difference was found (L=55, p=0.01, Figure 18) with higher diversity on the ungrazed site.

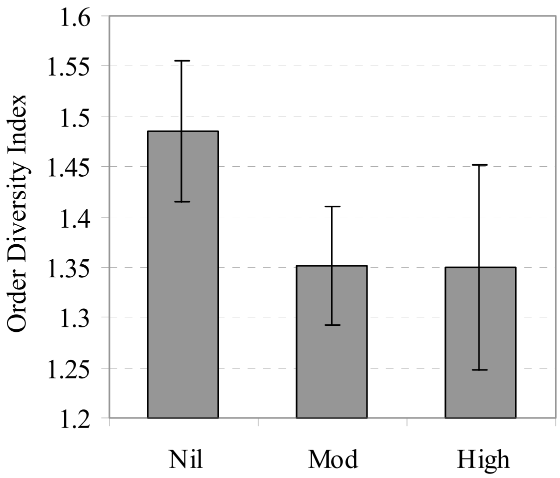


Figure 18: OLDMAN RIVER INVERTEBRATES
Insect order diversity decreased with increasing grazing intensity

3.2.3 Vegetation Results

a. Oldman River Vegetation

The Oldman River study showed distinct differences in vegetation composition and structure as grazing intensity changed. The number of shrub species decreased significantly with increased grazing intensity ($F_{2,6}$=5.34, p<0.05, Figure 19) as did the amount of shrub cover ($F_{2,6}$=12.98, p<0.01, Figure 20). Shrub cover is presented here as "cumulative shrub cover", the sum of the percent cover at each height layer. All shrub layers were reduced by grazing (measured at 0.5m, 1m, 2m, 3m and over 3m). Figure 21 shows a visual comparison of an ungrazed site and heavily grazed site from the Oldman study.

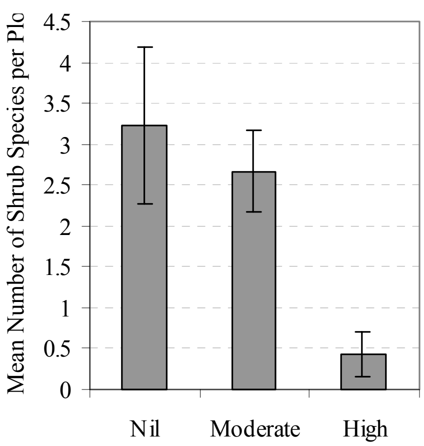


Figure 19: OLDMAN RIVER VEGETATION
The number of shrub species decreased with increasing grazing intensity

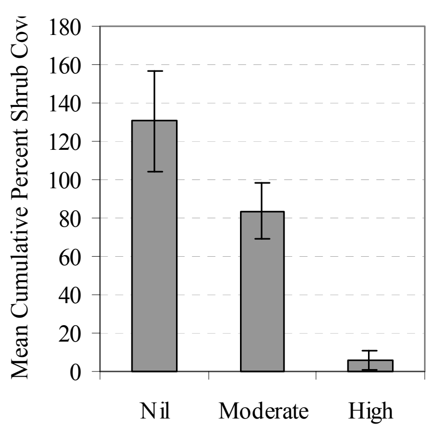


Figure 20: OLDMAN RIVER VEGETATION
The cumulative percent shrub cover decreased with increasing grazing intensity

Figure 21: Structural differences between heavily grazed (left) and ungrazed (right) cottonwood forests along the Oldman River

The number of forb and grass species did not vary with grazing level, however the ungrazed sites had fewer non-native grasses and forbs compared to the sites with high grazing intensity (Fisher's PLSD Nil Versus High, p=0.04, Figure 22)

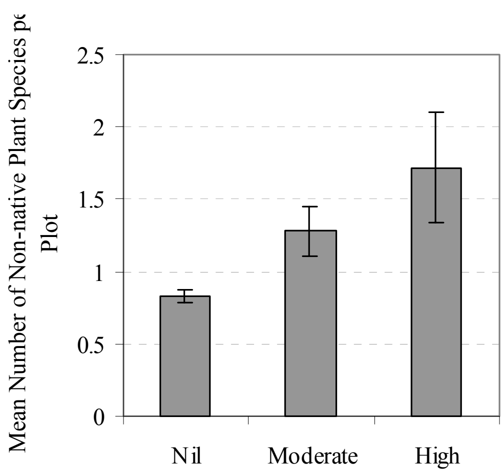


Figure 22: OLDMAN RIVER VEGETATION
The number of non-native plant species increased with increased grazing intensity

b. Oldman River Tree Health

Tree health declined with increases in grazing intensity (Figure 23). Heavily grazed sites averaged close to a score of "2" (50% alive, 50% dead limbs). Ungrazed sites averaged close to a score of "3" (more live than dead limbs). This relationship was statistically significant ($F_{2,5}$=14.80, p<0.01). The number of dead trees increased with grazing intensity ($F_{2,5}$=16.97, p<0.01).

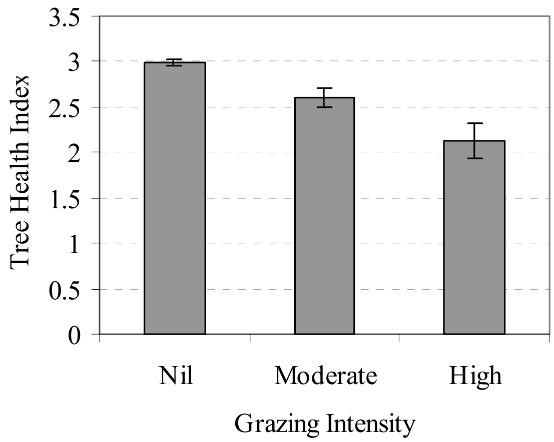


Figure 23: OLDMAN RIVER VEGETATION Tree health decreased with increased grazing intensity

3.2.4 Relationships Between Vegetation and Bird Community

a. Oldman River

In the Oldman River study, relationships between components of the bird community and vegetation variables were investigated. The most significant relationships found are summarized here:

1. A significant positive correlation between bird abundance and cumulative shrub cover* (r=0.73, p=0.02)
2. A significant positive correlation between bird species richness and shrub volume** (r=0.72, p=0.03)
3. A significant positive correlation between fall bird species richness and cumulative shrub cover* (r=0.77, p=0.02)
4. A positive relationship was observed between tree health indices and breeding bird abundance (r=0.69, p=0.06). No significant relationship was found between tree health and number of cavity nesters or woodpeckers.

*cumulative shrub cover = addition of all percent shrub cover for each layer (0.5, 1, 2, 3, 3+ m from the ground)
**shrub volume = addition of shrub cover multiplied by shrub height (thereby weighting the importance of taller shrubs)

4. New Data Analyses

4.1 Data Manipulation

Because many of the studies include bird species represented by only a few individuals, I tried to define a group of riparian breeding bird species that were common in all of the study sites. I termed this the "riparian assemblage". The riparian assemblage species were selected in the following manner:

The twenty most abundant native species from each of the five studies were listed. Bird species that were included in four or more of these "top 20 lists" were included in the riparian assemblage. The riparian assemblage consists of the following eleven species. The numbers in brackets indicate the number of studies in which the species was one of the most common twenty.

5. Mourning Dove (5)
6. Northern Flicker (4)
7. Eastern Kingbird (5)
8. Least Flycatcher (5)
9. Cedar Waxwing (4)
10. House Wren (5)
11. American Robin (5)
12. Yellow Warbler (5)
13. Warbling Vireo (4)
14. Clay-coloured Sparrow (5)
15. Brown-headed Cowbird (5)

For each study the bird information was summarized in the following manner:

16. Species Abundance (all species)*
17. Number of Species (all species)
18. Native Species Abundance (excludes European starlings and house sparrows)*
19. Number of Native Species (excludes European starlings and house sparrows)
20. Non-native Species Abundance*
21. Number of Non-native Species
22. Abundance of "Riparian Assemblage" species
23. Foraging Guilds - number of individuals in each of the following guilds:
    - aerial insectivore (e.g. eastern kingbird, least flycatcher)
    - bark insectivore (e.g. downy woodpecker, red-breasted nuthatch)
    - foliage insectivore (e.g. yellow warbler, gray catbird)
    - ground insectivore (e.g. American robin, brown thrasher)
    - carnivore (e.g. great horned owl, northern harrier)
    - omnivore (e.g. black-billed magpie, northern flicker)

* for the Suffield data, encounter rates were used instead of species abundance.

The Suffield data included waterfowl, primarily observed on the river while the floodplain forest was being surveyed. Because few of the waterfowl were directly using the riparian area, they were excluded from the analyses. Similarly, shorebirds that were most likely using gravel and sand bars in the river were also excluded (e.g. lesser yellowlegs and American avocet). Shorebirds that make use of the riparian area were retained (e.g. spotted sandpiper and killdeer).

4.2 Riparian Health Assessments

4.2.1 Methods

The Cows and Fish program, in conjunction with Dr. Paul Hansen from the University of Montana, have developed a method of assessing riparian health (Hansen et al., 2000). The Riparian Health Inventory measures a variety of vegetation and hydrological aspects of riparian areas along individual reaches of a stream or river. In 2000, riparian health inventories were conducted in the nine sites along Pothole Creek where breeding bird data were collected. They have also been conducted on the two Pekisko Creek sites and three of the Suffield riparian sites. The riparian health assessment inventory form is given in Appendix C.

The Pothole Creek study is the only study with sufficient sites for a statistical comparison of the riparian health assessment data and breeding bird data. The riparian health data were analysed with the bird data to produce Pearson correlation coefficients (r). The following riparian health data variables were selected:

1. Overall Health Rating (a percentage based on the soil/hydrology rating and vegetation rating
2. Soil/Hydrology Rating (a percentage score based on soil and streambank attributes)
3. Vegetation Rating (a percentage score based on vegetation attributes)

VEGETATION sub-categories

4. Vegetative Cover Score (0-6)
5. Invasive Plant Species Score (0- 6)
6. Disturbance-increaser Undesirable Herbaceous Species Score (0-3)
7. Preferred Tree and Shrub Species Establishment and Regeneration Score (0-6)
8. Utilization of Preferred Tree and Shrub Species Score (0-3)
9. Standing Decadent and Dead Woody Material Score (0-3)
10. Vegetation Subtotal (out of 27 – note this is the same score as used for the overall vegetation rating)
11. Vegetation Subtotal minus Utilization*
12. Vegetation Subtotal minus #8 (utilization), #5 (invasive plants) and #6 (disturbance species).*
13. Total canopy cover – trees (percentage)
14. Total canopy cover – shrubs (percentage)
15. Total canopy cover – grass(percentage)
16. Total canopy cover – forbs (percentage)
17. Total canopy cover by woody species (percentage)
18. Trees>6ft (percentage)
19. Shrubs>6ft (percentage)
20. Shrubs 1.5 - 6 ft (percentage)
21. Shrubs 0-1.5 ft (percentage)
22. Shrub Total - adding up the above three values (percentage)*
23. Shrub Volume 1 – multiplying the percent of each shrub layer with the average height of the layer, then adding these together, using 8 for the >6ft layer*
24. Number of shrub species
25. Number of shrub species represented by over 5% cover
26. Number of shrub species represented by over 1% cover
27. Infestation by weeds (percentage)
28. Undesirable herbaceous species (percentage)

* variables that are not directly included in the health assessment, but were calculated from health assessment variables for the purposes of this analysis.

4.2.2 Results

29. Pothole Creek

Table 5 shows the riparian health assessment data and breeding bird data for the nine Pothole Creek sites.

Table 5: Pothole Creek Riparian Health Assessments and Breeding Bird Data

(see listing on page 24-25 for units of measurement for the health rating variables)

Sites	1	2	3	1	2	3	1	2	3
LEVEL OF GRAZING INTENSITY		**NIL**			**MOD**			**HIGH**	
Overall Health Rating (%)	82	72	58	77	72	61	46	63	70
AVERAGE HEALTH RATING (%)		71			70			60	
Soil/Hydrology (%)	100	87	48	87	77	77	50	63	83
Vegetation Rating (%)	63	56	67	67	67	44	30	63	56
AVERAGE VEGETATION RATING (%)		62			59			50	
Vegetative Cover Score	6	6	6	6	6	6	2	6	6
Invasive Plant Species	0	0	0	0	0	0	0	0	0
Disturbance-increaser Undesirable Herbaceous Species	0	0	0	1	0	0	0	0	0
Preferred Tree and Shrub Species Establishment and Regeneration	6	6	4	6	6	4	4	6	6
Utilization of Preferred Tree and Shrub Species	2	1	1	2	3	1	0	2	1
Standing Decadent and Dead Woody Material	3	2	2	3	3	1	2	3	2
Vegetation Subtotal	17	15	13	18	18	12	8	17	15
Vegetation Subtotal minus Utilization	15	14	12	16	15	11	8	15	14
Vegetation Subtotal minus util, inv and dist.	15	14	12	15	15	11	8	15	14
Total canopy cover - trees	30	40	20	0.5	20	20	40	30	0.5
Total canopy cover - shrubs	50	60	80	60	70	60	50	30	70
Total canopy cover - grass	80	98	98	90	90	98	80	80	80
Total canopy cover - forbs	20	40	50	20	10	40	50	10	10
Total canopy cover by woody species	60	60	80	60	80	60	70	40	70
Trees>6ft	20	30	20	0.5	20	20	30	30	0.5
Shrubs>6ft	30	50	50	40	50	50	40	20	10
Shrubs 1.5 - 6 ft	20	10	20	30	20	10	10	10	30
Shrubs 0-1.5 ft	30	3	10	10	0.5	0.5	0.5	0.5	40
Shrub Volume 1 (add up 3 layers)	80	63	80	80	71	61	51	31	80
Number of shrub species	10	14	14	9	13	11	12	7	8
Number of shrub species over 5% cover	4	3	4	6	5	3	3	2	4
Number of shrub species over 1% cover	6	6	12	9	8	6	8	5	6
Percent infestation by weeds	4	8	8	6	7	7	6	7	7
Percent undesirable herbaceous species	4	6	7	4	5	5	7	7	5
BIRD DATA		**NIL**			**MOD**			**HIGH**	
ALL SPECIES									
Abundance	102	102	92	69	86	52	76	47	42
Number of Species	28	27	25	22	24	17	24	21	11
NATIVE SPECIES									
Abundance	101	102	90	67	84	51	62	42	42
Number of Species	27	27	23	21	22	16	23	19	11
NON-NATIVE SPECIES									
Abundance	1	0	2	2	2	1	14	5	0
RIPARIAN ASSEMBLAGE									
Abundance	41	61	53	35	44	32	35	29	26
FORAGING GUILDS									
aerial insectivore	17	18	9	3	7	3	6	8	2
bark insectivore	0	0	0	0	0	0	0	1	0
foliage insectivore	30	30	31	19	26	16	21	14	9
ground insectivore	22	33	29	26	22	21	17	14	19
carnivore	1	1	1	0	2	0	0	1	0
omnivore	30	20	20	18	26	11	18	4	12

The results of the analyses are shown in Table 6 (note: only the vegetation variables where some correlation values are <0.10 are presented).

Table 6: Correlation Values of Riparian Health Assessment Variables and Bird Variables for Pothole Creek (using Pearson's correlation parametric test)
*p<0.10; **p<0.05; ***p<0.01; values of p<0.10 in **bold**

							Foraging Guilds					
	All Species Abund.	Species Richness	Native Species Abund.	Native Species Richness	Non-native Species Abundance	Riparian Assemb. Abund.	AI	BI	FI	GI	C	OM
Overall Health Rating	0.252	0.123	0.381	0.163	**-0.747****	0.126	0.343	-0.129	0.171	0.321	0.296	0.423
Soil/Hydrology	0.150	-0.004	0.264	0.075	**-0.647***	0.001	0.302	10.248	0.026	0.224	0.040	0.352
Vegetation Rating	0.210	0.181	0.326	0.134	**-0.667****	0.252	0.202	0.178	0.262	0.337	0.575	0.230
Vegetative Cover Score	-0.029	-0.134	0.145	-0.146	**-0.940*****	0.149	0.136	0.125	0.037	0.351	0.354	-0.16
Invasive Plant Species	No significant relationships											
Disturbance-increaser Undesirable Herbaceous Species	No significant relationships											
Preferred Tree and Shrub Species Establishment and Regeneration	No significant relationships											
Utilization of Preferred Tree and Shrub Species	0.105	0.175	0.185	0.111	-0.452	-0.003	0.086	0.236	0.123	-0.029	**0.668****	0.276
Standing Decadent and Dead Woody Material	No significant relationships											
Vegetation Subtotal	0.064	0.080	0.181	0.059	**-0.646***	0.030	0.176	0.252	0.046	0.134	0.499	0.174
Vegetation Subtotal minus Utilization	0.047	0.043	0.171	0.038	**-0.682****	0.040	0.199	0.245	0.016	0.184	0.416	0.131
Vegetation Subtotal minus util, inv and dist.	0.061	0.046	0.188	0.040	**-0.701****	0.062	0.253	0.273	0.035	0.163	0.483	0.135
Total canopy cover - trees	0.489	**0.648***	0.389	**0.659***	0.464	0.446	**0.676****	0.197	0.492	0.013	0.314	0.156
Total canopy cover - shrubs	0.249	-0.128	0.318	-0.118	-0.412	0.393	-0.175	**-0.746****	0.280	**0.587***	0.081	0.390
Total canopy cover - grass	0.312	0.186	0.383	0.187	-0.436	**0.635***	0.097	-0.369	0.421	**0.765****	0.144	0.100
Total canopy cover - forbs	No significant relationships											
Total canopy cover by woody species	No significant relationships											
Trees>6ft	No significant relationships											
Shrubs>6ft	0.577	0.545	0.559	0.527		**0.676****	0.205	-0.450	**0.655***	**0.612***	0.278	0.411
Shrubs 1.5 - 6 ft	No significant relationships											
Shrubs 0-1.5 ft	No significant relationships											
Shrub Volume 1 (add up 3 layers)	0.360	-0.003	0.449	0.037	-0.539	0.253	0.012	**-0.780****	0.314	0.548	-0.022	**0.629***
Shrub Volume 2 (multiply and then add, using 8 for the >8ft layer)	**0.607***	0.506	**0.610***	0.495	-0.112	**0.682****	0.166	-0.585	**0.672****	**0.694****	0.260	0.514
Number of shrub species	**0.734****	0.560	**0.708****	0.569	0.022	**0.844*****	0.400	-0.576	**0.777****	**0.676****	0.390	0.554
Number of shrub species over 5% cover	No significant relationships											
Number of shrub species over 1% cover	No significant relationships											
Percent infestation by weeds	No significant relationships											
Percent undesirable herbaceous species	No significant relationships											

Shrub volume (the sum of the percent cover at each height class multiplied by the shrub height) and the number of shrub species were found to be the strongest predictors of the bird community. Both of these measures were positively correlated with the total bird abundance, native bird abundance, abundance of riparian assemblage species, abundance of foliage insectivores and abundance of ground insectivores. However, it would be premature to assume that this might apply to other riparian sites on the basis of one data set.

Non-native species were negatively correlated with a number of health variables including the overall health rating, soil/hydrology rating, and the vegetation rating. It should be noted that many of the health variables were correlated with each other. One unexplained relationship was the strong positive correlation between utilization of trees and shrubs (by browsers) and the number of birds in the carnivorous foraging guild (raptors). Considering the simplicity of the utilization score scale (0-3), the low numbers of raptors (e.g. either 0, 1 or 2), and the fact that raptors require a foraging territory much larger than the bird count circles, this relationship is probably a sampling anomaly.

b. Pekisko Creek

As there were only two sites at Pekisko Creek, it is not possible to do any correlations between riparian health assessment data and bird variables. The lightly grazed site received a higher overall health rating (79%) than the heavily grazed site (52%) and the bird studies generally indicate higher abundance of native species and the riparian assemblage on the lightly grazed site. Table 7 shows the results of the riparian health assessments (conducted in one year) and the results of the bird studies (conducted over four consecutive years). It should be noted that the Pekisko Creek health assessments were done before changes were made to the inventory process, thus some of the variables are absent as they were not collected in the earlier version of the inventory (n/c in Table 7).

Table 7: Riparian Health Assessment Data and Bird Data for Pekisko Creek.

n/c = not collected as part of this riparian health assessment

	MacPherson	Bar U
RIPARIAN HEALTH ASSESSMENT DATA	Light	High
Overall Health Rating	79	52
Soil/Hydrology	n/c	n/c
Vegetation Rating	n/c	n/c
VEGETATION sub-categories		
1.Vegetative Cover Score	6	4
2. Invasive Plant Species	4	2
3. Disturbance-increaser Undesirable Herbaceous Species	2	1
4. Preferred Tree and Shrub Species Establishment and Regeneration	6	4
5. Utilization of Preferred Tree and Shrub Species	2	2
6. Standing Decadent and Dead Woody Material	n/c	n/c
Vegetation Subtotal	20	13
Vegetation Subtotal minus Utilization	18	11
Vegetation Subtotal minus util, inv and dist.	12	8
Number of Shrub Species	12	6

Table 7 : Riparian Health Assessment Data and Bird Data for Pekisko Creek. (Continued)

BIRD DATA	MacPherson 1994 Mod	Bar U 1994 High	MacPherson 1995 Mod	Bar U 1995 High	MacPherson 1996 Mod	Bar U 1996 High	MacPherson 1997 Mod	Bar U 1997 High
All Bird Species								
Abundance	34	29	54	39	72	55	46	45
Number of Species	15	10	22	9	23	10	23	15
Native Bird Species								
Abundance	29	12	50	17	58	12	42	29
Number of Species	14	9	21	8	22	8	22	14
Non-native Birds								
Abundance	5	17	4	22	14	43	4	16
Riparian Assemblage								
Abundance	21	6	36	13	38	5	30	13
Foraging Guilds								
Aerial insectivore	6	0	12	4	14	1	10	4
Bark insectivore	1	1	1	1	2	1	1	1
Foliage insectivore	10	4	20	8	19	3	16	7
Ground insectivore	8	3	9	1	10	1	9	3
Carnivore	0	1	1	0	2	3	1	1
Omnivore	4	3	6	1	11	3	5	12

c. South Saskatchewan Suffield

Riparian health assessments were completed for three riparian areas along the South Saskatchewan River where bird data were collected. The health assessment data and bird data are presented in Table 8. The sample size is insufficient for statistical analysis. However, examination of the data indicates that increases in grazing resulted in decreases in shrub volume, which corresponds with a decrease in the abundance of native bird species and the abundance of riparian assemblage species. Unlike the Pothole Creek study, the number of shrub species was lower in the ungrazed site (8) than the two grazed sites (each with 11 species). Although, when coverage is considered, the number of shrub species represented by over 5% cover decreases with increased grazing (Nil = 7, Mod = 4, High = 4). There were no significant correlations found between shrub coverage over 5% and bird variables in the Pothole Creek analysis.

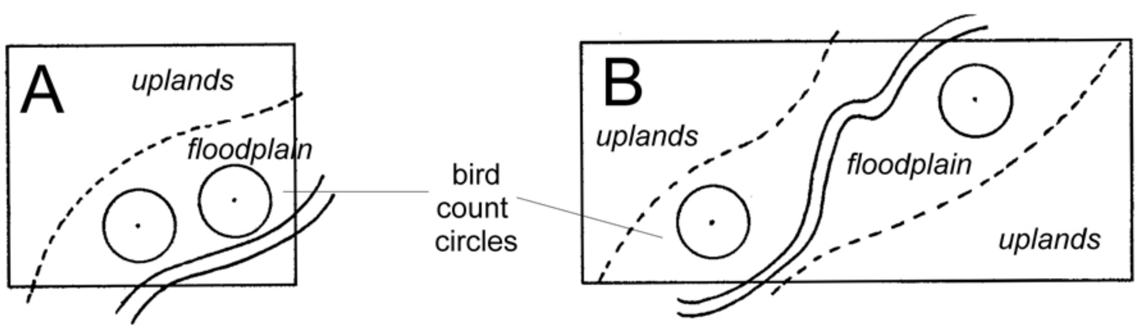
Table 8: Riparian Health Assessment Data and Bird Data for South Saskatchewan Suffield

	Sherwood	Dugway	Bullpen
RIPARIAN HEALTH ASSESSMENT DATA	Nil	Mod	High
Overall Health Rating	79	74	40
Soil/Hydrology	90	90	43
Vegetation Rating	67	56	37
1.Vegetative Cover Score	6	4	2
2. Invasive Plant Species	0	0	0
3. Disturbance-increaser Undesirable Herbaceous Species	1	1	1
4. Preferred Tree and Shrub Species Establishment and Regeneration	6	6	4
5. Utilization of Preferred Tree and Shrub Species	2	1	0
6. Standing Decadent and Dead Woody Material	3	3	3
Vegetation Subtotal	18	15	10
Vegetation Subtotal minus Utilization	16	14	10
Vegetation Subtotal minus util, inv and dist.	15	13	9
Total canopy cover - trees	30	30	30
Total canopy cover - shrubs	80	70	60
Total canopy cover - grass	80	60	60
Total canopy cover - forbs	80	30	20
Total canopy cover by woody species	90	70	60
Trees>6ft	20	20	30
Shrubs>6ft	50	40	30
Shrubs 1.5 - 6 ft	20	20	30
Shrubs 0-1.5 ft	10	10	10
Shrub Volume 1 (add up 3 layers)	80	70	70
Shrub Volume 2 (multiply and then add)	452.5	372.5	315.0
Number of shrub species	8	11	11
Number of shrub species over 5% cover	7	4	4
Number of shrub species over 1% cover	7	8	5
Percent infestation by weeds	8	6	5
Percent undesirable herbaceous species	3	4	3
BIRD DATA			
ALL SPECIES			
Average Encounter Rates/Abundance	35.35	28.74	37.89
Number of Species	121	84	78
NATIVE SPECIES			
Average Encounter Rates/Abundance	33.27	21.60	30.30
NON-NATIVE SPECIES			
Average Encounter Rates/Abundance	2.08	7.14	7.58
COMMON RIPARIAN ASSEMBLAGE			
Average Encounter Rates/Abundance	11.72	6.80	4.68
FORAGING GUILDS			
aerial insectivore	1.95	3.10	1.17
bark insectivore	0.42	3.91	0.11
foliage insectivore	16.03	5.63	6.56
ground insectivore	5.75	3.46	5.95
carnivore	1.17	1.19	1.98
omnivore	7.92	6.25	14.53

4.2.3 Discussion

On the basis of the one study (Pothole Creek) where both health assessment and bird data are available, it is not possible to draw any strong conclusions regarding relationships between the riparian health measures and the bird community. However, some of the shrub measures, particularly shrub volume, may be useful indicators of bird community health. This reflects the findings of the Oldman River study where shrub cover was found to be the best predictor of bird abundance and richness. The Suffield data support only the usefulness of the shrub volume measure (the sums of percent cover for each shrub layer multiplied by the height of the layer) and not the total number of shrub species present, except when only those represented by over 5% cover are considered. Additional studies where at least nine sites are employed will be required to investigate this further.

There are a number of reasons why there were relatively few strong correlations between the Pothole Creek riparian health assessment variables and the bird data (e.g. there was no relationship between the overall health rating or vegetation rating and the bird variables). Firstly, the health assessments were conducted over the entire site, compared to the bird surveys which were conducted in a more restricted area; two 50m radius circles. Because of the relatively narrow nature of the riparian zone along Pothole Creek, the bird count circles were most often positioned in the widest parts of the floodplain so as accommodate the circle. It is possible that this biased the sample (i.e. it is possible that the riparian vegetation was different in the count circles versus the entire site). In addition, in some small sites (a quarter section or less) the count circles covered almost the entire riparian portion of the site, while in other sites the count circles were sampling only a small percentage of the total riparian area (Figure 24).



A. In sites like this one, the riparian health assessments were measuring a similar area to the area sampled during the bird surveys

B. In sites like this one, the riparian health assessments sampled a more extensive area than was sampled for birds

Figure 24: Differences in Aerial Coverage of Bird Counts Versus Riparian Health Assessments

Riparian areas tend to have a high amount of within-site variability in vegetation structure and composition. This could explain the anomaly with Pothole Creek site “1Nil”, which is a large site that was ungrazed and in excellent health, but scored surprisingly low in “shrubs >6ft”. The site contains a large cattail complex, only a small part of which was included in a bird count circle. Because the cattail complex takes up a portion of the riparian area, this would negatively influence the overall shrub coverage.

While useful for an index of overall riparian health, the methods used in the health assessments represent a course filter approach and are perhaps too crude to detect vegetation differences that result in differences in the bird populations. For example, although the sites differ quite dramatically in grazing intensity (from ungrazed sites to sites that are grazed year-round), there is little variation in the overall vegetation scores between the ungrazed sites (average of 62%), moderately grazed sites (average of 59%) and heavily grazed sites (average of 50%). These relatively low vegetation scores are in part because all sites scored 0 in the “invasive plant species” category (>15% weed infestation) and only one site scored above 0 in the “disturbance-increaser undesirable herbaceous species” category (>15% undesirable species). In the Oldman River study, where vegetation was measured using sampling quadrats, a significant correlation was found between shrub layers (particularly shrub volume) and bird abundance and richness (see page 22). In the riparian health assessments, the percentage of shrubs in each of three height layers is estimated by a visual estimate of the entire site, a much faster but less accurate method. Unlike Pothole Creek, the Oldman study also showed significant differences in the numbers of invasive weed species between the three grazing levels.

In addition, there may be factors other than grazing that result in vegetation and bird differences. For example, although site “3Nil” had not been grazed for at least 30 years, it is an area that has experienced human disturbance historically (from early settlement). It is also the site closest to an urban area and experiences more current human disturbance than the other sites. This site had the lowest bird abundance and richness of the three ungrazed sites. It also had a fairly low overall riparian health rating, again possibly a result of past human disturbance.

4.3 Data Meta-analysis

Each of the studies investigated in this report has merit on its own. The Oldman breeding bird study, the Oldman fall birds study, and the Pothole Creek study each have replicates of grazing treatments, so the conclusions from each study have some generality with respect to the effects of grazing on bird communities. Lack of replication of grazing treatments is a common problem in many riparian grazing studies, making interpretation troublesome (Belsky et al. 1999). The Pekisko Creek breeding bird study is not replicated by treatment, but each of the two study sites is replicated in time across four years. Analyses within this study confirm the same general grazing effect across years (see section 3.2.1.a). The Suffield Study also has no replication by treatment. Technically, there was replication in time, but only the summary data were available for this analysis. Thus, the Suffield results parallel the impact of grazing effect observed in other studies, but do not lend themselves to statistical analysis. It should be noted that the data in the Suffield study were not originally collected with the intent of statistically analysing the influence of grazing. The Leader study is well replicated, but there is limited information available on grazing intensities (sites were classified as grazed or ungrazed). Site descriptions suggest that grazing was extremely light. The primary focus of the Leader study was to provide an overview of the avifauna of the area, not to gather data for an analysis of the effects of grazing.

While each of these studies provides localized information on the impacts of grazing on riparian birds, one of the goals of this report is to examine this effect across studies to involve broader geographical and temporal ranges.

This requires a method of assessing the results of each study in an objective way, and then combining the results in an attempt to draw a general conclusion. Such a method is provided by meta-analysis; the combination of the results of several independent experiments for a combined re-analysis. (Gurevitch & Hedges 1993).

Despite the fact that methods vary considerably between studies, there is a question common to all studies: Does increased grazing pressure result in diminished bird communities? For the purposes of this meta-analysis the following grazing treatments were included: for the Oldman and Pothole studies the nil and high grazing categories were used; for Pekisko Creek, the categories light and high were used; and for Leader, nil and light were used. Suffield data were not used because there was no replication in time or space, and thus variance could not be estimated.

4.3.1 Methods

To examine the influence of grazing on riparian birds it was necessary to develop a common definition of the "effect" to be examined. In this case I used the greatest potential difference in grazing categories. For example, in the Oldman breeding birds study the greatest difference between grazing categories was between Nil and High, whereas in the Pekisko Creek study the most extreme difference between grazing categories was between Light and High because there were no ungrazed sites.

For each measure of bird community structure (e.g. abundance of all species, abundance of native species, species richness, etc.), the difference in effect was calculated within each study by subtracting the mean value for the highest grazing category from the mean value for the lowest grazing category. This difference was then divided by the pooled standard deviation to create a standardized difference score:

$$d \text{ (standardized difference score)} = \frac{\text{mean native species lowest grazing category} - \text{mean native species highest grazing category}}{\text{pooled standard deviation}}$$

For example, the calculation for the number of native species in the Oldman Breeding bird study is as follows:

$$d = \frac{23 - 16}{4.12} = 1.70$$

Each difference score was weighted by factors that controlled for sample size and sampling variance. For example, studies with large sample sizes, such as the Leader study, were weighted more heavily than those with lower sample sizes. The combined effect was simply the sum of these difference scores which was tested against a z-score (see Gurevitch & Hedges 1993 for details). I used one-tailed tests because the direction of the grazing effects on bird community health was predicted beforehand (i.e. increased grazing pressure would cause a decrease in bird community health).

The Pekisko Creek data may violate the assumption of independence of samples required for a meta-analysis. For this analysis a site is considered to be the basic sampling unit and thus repeated samples across four years do not represent four completely independent replicates. However, to estimate variance between the grazing treatments the yearly measures must be treated as replicates. I justify this method for two reasons: Firstly, the analysis is conservative (i.e. it errs on the side of finding no difference) because the between-subject design underestimates the true difference within each year, and the variance is over-estimated. Secondly, there is some true independence between years due to replacement of individuals through mortality and habitat choice.

4.3.2 Results

The data were analysed twice, with and without the Leader sites. In Table 9, values of "d" represent the combined difference effect between conditions of higher and lower grazing intensity. Positive values indicate healthier avian communities in the lower grazing condition. Measures of species richness (all species and native species) show a negative impact of grazing (Table 9). This effect was stronger when the Leader data were excluded. Grazing showed significant impacts on bird abundance only when the Leader data were excluded (Table 9). Significant effects were also evident in the numbers of individuals in specific groups or guilds, such as common riparian birds, aerial insectivores, and foliage insectivores (Table 9).

Table 9: Results of the meta-analysis of the impact of higher and lower grazing pressure on avian community variables.

d = combined difference effect between higher and lower grazing intensity
ns = not significant, statistically significant results ($p<0.05$) are shown in **bold**

	All Inds.	All Spp.	Native Inds.	Native Spp.	Non-native Inds.	Rip. Assemblage	Aerial Insect.	Bark Insect.	Foliage Insect.	Ground Insect.	Carn.	Omn.
						With Leader						
d	0.33	**0.54**	0.49	**0.58**	0.05	**0.57**	**0.54**	0.42	**0.91**	0.26	0.19	0.35
p	ns	**0.05**	ns	**0.05**	ns	**0.05**	**0.05**	ns	**0.01**	ns	ns	ns
						Without Leader						
d	**1.47**	**1.63**	**2.51**	**1.91**	-0.59	**2.23**	**0.56**	0.422	**3.00**	**1.834**	-0.03	**1.32**
p	**0.01**	**0.01**	**0.01**	**0.01**	ns	**0.01**	**0.01**	ns	**0.01**	**0.01**	ns	**0.01**

4.3.3 Discussion

The meta-analysis, incorporating studies from Alberta and Saskatchewan, demonstrates a general negative effect of grazing on species richness across a broad geographic area in Alberta and into western Saskatchewan. There is also a general negative effect of grazing on native bird abundance, which is statistically significant when the Leader data are excluded from the analyses. As discussed elsewhere, the levels of grazing on the Leader sites were not specifically defined. They all appear to be grazed lightly, so the difference between grazed and ungrazed is small. Common riparian birds (riparian assemblage) and birds in the foliage insectivore, ground insect and omnivore guilds experience a general negative effect by grazing across all studies (both with and without the Leader study).

4.4 Foraging Guilds and Individual Species Response to Grazing

4.4.1 Foraging Guilds

Table 10 shows the response of individual foraging guilds to grazing. Considering that overall bird abundance generally decreases with grazing intensity, it is not surprising that this is the predominant trend within most foraging guilds.

Table 10: Response of Foraging Guilds to Grazing (shown as mean number of birds in each guild per site)

	SUFFIELD			POTHOLE			PEKISKO		OLDMAN Breeding			LEADER		OLDMAN Fall		
	Nil	Mod	High	Nil	Mod	High	Mod	High	Nil	Mod	High	Nil	Light	Nil	Mod	High
Aerial insectivore	1.9	3.1	1.2	14.7	4.3	5.3	10.5	2.3	21.3	14.7	11.3	0.9	0.8	7.7	3.7	5.7
Bark insectivore	0.4	3.9	0.1	0.0	0.0	0.3	1.3	1.0	3.0	1.7	0.7	0.0	0.0	7.3	3.7	3.7
Foliage insectivore	16.0	5.6	6.6	30.3	20.3	14.7	16.3	5.5	60.7	34.3	19.3	4.8	4.9	57.0	49.3	19.0
Ground insectivore	5.8	3.5	6.0	28.0	23.0	16.7	9.0	2.0	27.0	14.0	17.3	2.9	2.0	40.0	21.0	18.3
Carnivore	1.2	1.2	2.0	1.0	0.7	0.3	1.0	1.3	0.7	1.3	1.3	0.1	0.2	3.0	2.3	4.0
Omnivore	7.9	6.3	14.5	23.3	18.3	11.3	6.5	4.8	16.0	6.0	9.7	4.0	3.3	29.0	22.7	9.0

Note that abundance has been averaged for all sites with the same grazing level for the Pothole, Leader and Oldman studies. Abundance was averaged across years for Pekisko. The Suffield values are encounter rates per hour and they include observations during the migration periods as well as the breeding season.

With the exception of the Leader study, the number of birds in the foliage insectivore guild decreases with grazing in all studies. This is not unexpected as grazing tends to reduce or remove the shrub layer, decreasing the foraging opportunities for birds in the foliage insectivore guild. Ground insectivores and omnivores are also present in higher numbers in ungrazed sites, with the exception of the Suffield study.

4.4.2 Individual Species

A complete species list of all birds found in the six studies is included in Appendix B. Table 11 summarizes the responses found in each study by species (excluding aquatic species). Because of the differing survey methods employed between studies, it is not possible to draw statistical conclusions about individual species response to grazing, however qualitative comparisons can be made across the studies. It should be noted that because the information in Table 11 is largely qualitative, caution should be taken in drawing conclusions about individual species responses to grazing, especially for those species that were recorded in low numbers.

Table 11: Individual Species Response to Grazing.

A downward arrow (↓) indicates that the species generally decreased in abundance with increases in grazing intensity. An upward arrow (↑) indicates that the species increased in abundance with increases in grazing intensity. **N** indicates that there was no clear trend in either direction. The number in brackets indicates the total number of that species that were recorded in the study. Where 10 or more individuals were recorded in a study, the results are presented in **bold**.

Species	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Northern Harrier	↓ (1)			↓ (2)	**↓ (11)**	
Sharp-shinned Hawk					↓ (6)	
Cooper's Hawk		↓ (4)			↑ (1)	
Broad-winged Hawk					↓ (3)	
Swainson's Hawk	N (1)				N (4)	
Red-tailed Hawk	↑(5)	N (3)	N (4)	N (2)	N (5)	
American Kestrel	↑(5)	↑(5)	↓ (5)	↓ (2)	**↑ (75)**	↓ (4)
Merlin		↓ (5)			N (41)	
Prairie Falcon					↓ (1)	
Gray Partridge					↑ (4)	
Ring-necked Pheasant	↓ (2)			**↓ (21)**	↓ (1)	↑ (5)
Sharp-tailed Grouse					↑ (2)	
Ruffed Grouse			↓ (3)			
Sora				↓ (1)	↓ (1)	
Killdeer					**↓ (26)**	
Spotted Sandpiper				↓ (5)	**↓ (21)**	↓ (3)
Common Snipe			↓ (2)		↑(1)	
Rock Dove					**↑(17)**	
Mourning Dove	**↓ (23)**	N (44)	↓ (4)	**↓ (16)**	N (60)	**↑(17)**
Black-billed Cuckoo					↓ (1)	↓ (1)
Great Horned Owl	↑(2)	↑(9)			↑(3)	
Long-eared Owl					↓ (1)	
Common Nighthawk					N (86)	↑(1)
Belted Kingfisher					↓ (3)	
Yellow-bellied Sapsucker	↓ (1)				↓ (5)	
Red-naped Sapsucker			↓ (3)		N (2)	
Downy Woodpecker	**↓ (10)**	N (22)		↑(1)	N (12)	
Hairy Woodpecker	N (5)	**↓ (11)**	N (2)		N (2)	
Northern Flicker	**↑(16)**	**↓ (54)**	↓ (6)	↓ (1)	N (71)	**↓ (19)**
Pileated Woodpecker					↓ (1)	
Olive-sided Flycatcher				↓ (1)	↓ (1)	
Western Wood Pewee	**↓ (30)**	**↓ (24)**	**↓ (14)**	**↓ (14)**	N (9)	↑(1)
Alder Flycatcher			↓ (1)	↓ (2)	N (1)	
Least Flycatcher	**↓ (75)**	**↓ (15)**	**↓ (32)**	**↓ (18)**	**↓ (48)**	**↑(18)**
Say's Phoebe					N (2)	
Western Kingbird	N (6)			↓ (2)	**↑(21)**	↓ (2)
Eastern Kingbird	N (15)		N (9)	**↓ (18)**	N (73)	**↑(10)**
Loggerhead Shrike					↓ (5)	
Blue-headed Vireo					N (1)	
Cassin's Vireo				↓ (1)		
Philadelphia Vireo		↓ (1)				
Warbling Vireo	**↓ (18)**	↓ (5)	↓ (6)	N (7)	**↓ (15)**	**↑ (10)**

Species	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Red-eyed Vireo	↓ (1)	↓ (2)	↓ (1)	↓ (1)	N (4)	↓ (2)
Blue Jay						↓ (1)
Black-billed Magpie	N (11)	**↓ (34)**	↓ (6)	**↓ (16)**	N (204)	**↓ (17)**
American Crow	↓ (4)			N (5)	**↑(16)**	**↓ (18)**
Horned Lark					**↑(25)**	↑ (1)
Tree Swallow	**↓ (15)**		↓ (1)	**↓ (15)**	**↑(32)**	
Violet-green Swallow					↑(8)	
Northern Rough-winged Swallow				↓ (2)	N (10)	
Bank Swallow					**↓ (12)**	
Cliff Swallow					N (1)	
Barn Swallow					N (5)	
Black-capped Chickadee	**↓ (19)**	**↓ (88)**	↑(1)	↑(2)	N (25)	↑(7)
Red-breasted Nuthatch		↓ (6)	↑(4)		N (26)	
White-breasted Nuthatch		↓ (5)				
Brown Creeper					N (1)	
House Wren	**↓ (128)**	N (28)	**↓ (38)**	**↓ (31)**	N (208)	**↓ (58)**
Marsh Wren					↓ (2)	
Ruby-crowned Kinglet		N (16)			**↓ (29)**	
Golden-crowned Kinglet		↑(1)				
Mountain Bluebird	↑(1)	↑(8)				
Veery	↓ (6)					**↓ (16)**
Swainson's Thrush		↓ (6)			**↑(33)**	
Hermit Thrush					↓ (1)	
American Robin	N (102)	**↓ (178)**	**↓ (19)**	**↓ (32)**	**↓ (167)**	**↑(15)**
Gray Catbird	**↓ (34)**	**↓ (27)**	↓ (2)	**↓ (26)**	**↓ (16)**	**↓ (13)**
Brown Thrasher	N (1)	N (6)		↓ (2)	**↓ (66)**	↑(2)
European Starling	**↑(29)**	**↓ (160)**	**↑(115)**	**↑(24)**	**↑(693)**	↓ (2)
American Pipit					N (21)	
Sprague's Pipit					↓ (1)	
Cedar Waxwing	**↓ (32)**	**↓ (25)**	↓ (7)	**↓ (31)**	**↓ (199)**	↓ (5)
Tennessee Warbler					**↓ (56)**	
Orange-crowned Warbler		**↓ (15)**			N (104)	
Yellow Warbler	**↓ (90)**	**↓ (14)**	**↓ (30)**	**↓ (77)**	**↓ (196)**	**↑(55)**
Yellow-rumped Warbler		**↓ (119)**			N (578)	
Townsends Warbler						
Palm Warbler					↓ (4)	
Blackpoll Warbler					N (20)	
Black and white Warbler					↓ (2)	
American Redstart					↓ (1)	
Ovenbird					N (4)	
Northern Waterthrush					↑(3)	
MacGillivray's Warbler					N (2)	
Common Yellowthroat	↓ (1)	↓ (3)		**↓ (21)**	**↓ (83)**	↓ (8)
Wilson's Warbler		N (24)			N (17)	
Yellow-breasted Chat					**↓ (12)**	**↑(14)**
Western Tanager			↑(1)			

Species	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Spotted Towhee		N (2)			**↓ (101)**	**↑(44)**
American Tree Sparrow					↓ (2)	
Chipping Sparrow		N (10)			**↑(148)**	
Clay-coloured Sparrow	↓ (6)	↓ (1)	↓ (7)	N (52)	**↑(69)**	**↓ (25)**
Vesper Sparrow				(1)	**↑(15)**	**↑(10)**
Lark Sparrow					**↑(18)**	↑(8)
Lark Bunting					↓ (9)	
Savannah Sparrow					**↑(21)**	
Fox Sparrow					↓(1)	
Song Sparrow	↓ (1)		↓ (2)	**↓ (13)**	N (22)	
Lincoln's Sparrow		N (3)	↓ (9)		**↓ (56)**	
Swamp Sparrow						
White-throated Sparrow		**↓ (33)**			**↑(41)**	
Harris' Sparrow					N (3)	
White-crowned Sparrow		**↓ (13)**			N (165)	
Dark-eyed Junco		↓ (2)			**↑(22)**	
Rose-breasted Grosbeak					N (4)	
Black-headed Grosbeak	↓ (1)					
Lazuli Bunting						↓ (1)
Bobolink						↑ (1)
Red-winged Blackbird	↓ (1)			**↓ (57)**	**↓ (42)**	
Western Meadowlark		↓ (1)			**↑ (92)**	**↑(18)**
Yellow-headed Blackbird				↓ (9)	N (3)	
Brewer's Blackbird			↑(1)		**↑ (153)**	↑(1)
Common Grackle					↓ (2)	
Brown-headed Cowbird	**↓ (46)**		↓ (4)	**↓ (73)**	**↓ (57)**	**↑(10)**
Baltimore Oriole		↓ (4)	**↓ (11)**	↓ (7)	N (31)	↓ (3)
Purple Finch					N (2)	
Red Crossbill					N (9)	
Pine Siskin		N (4)	**↑(10)**		N (13)	↑(5)
American Goldfinch	**↓ (36)**	**↓ (23)**	↓ (1)	**↓ (42)**	**↓ (46)**	↑(4)
House Sparrow				N (3)	N (2)	↓ (1)

Abundant species (those recorded in at least three of the six studies and where N>9 for at least two studies) that showed a downward trend in two or more of the six studies are shown in Table 12.

Table 12: Abundant Riparian Species Showing a Decrease in Numbers with Grazing in Three or More of the Studies

Species	Number of studies the species occurred in	Number of studies in which the species declined with grazing	Percentage of studies where a downward trend was observed
Northern flicker	6	4	67%
Mourning dove	6	3	50%
Western wood pewee	6	4	67%
Least flycatcher	6	5	83%
Warbling vireo	6	4	67%
Black-billed Magpie	6	4	67%
Tree Swallow	4	3	75%
House wren	6	4	67%
American robin	6	4	67%
Gray catbird	6	6	100%
Cedar waxwing	6	6	100%
Yellow warbler	6	5	83%
Common yellowthroat	5	5	100%
Red-winged blackbird	3	3	100%
Brown-headed cowbird	5	4	80%
American goldfinch	6	5	83%

The information in Table 12 suggests that the following species may be good indicators of riparian health in the prairie areas of Alberta and Saskatchewan: least flycatcher, gray catbird, cedar waxwing, yellow warbler, common yellowthroat, red-wing blackbird and American goldfinch. Not surprisingly, these species primarily rely on the shrub component of riparian areas for foraging and nesting.

A few species increased in abundance with grazing. European starlings showed the strongest effect, being two to nine times more abundant in heavily grazed sites compared to ungrazed sites. Great horned owls, although not found in large numbers, increased with grazing in the three studies in which they occurred. Open-country and grassland bird species increased with grazing in some of the studies (e.g. vesper sparrow, western meadowlark and Brewer's blackbird). Presumably in these situations, heavy grazing is opening up the riparian forest to a point where it starts to become useable by grassland species.

For some species, it appears that there may be seasonal changes in response to grazing. For example, the American robin showed no clear trend in response to grazing in the Oldman River breeding bird study. However in the fall, robins were more abundant in ungrazed sites. This likely relates to seasonal differences in their foraging habits (primarily insects during the breeding season and berries in the fall). This was also the case along the Oldman River with the European Starling, which was most abundant in heavily grazed sites during the breeding season, but was found to be more abundant in ungrazed habitats in the fall.

It should be noted that with the exception of the Suffield study, all the breeding bird studies were conducted in June and into early July. This means that species which nest early in the season were likely less conspicuous in

June and therefore may have been underrepresented in these studies. Species for which this may apply include house sparrow, European starling and most of the woodpeckers.

4.5 Comparison of Relative Abundance and Species Richness Among Studies

Because the Suffield work did not use count circles in the riparian areas, it cannot be included in a comparison of abundance and species richness among studies. Caution is required when drawing conclusions about abundance and species richness in comparisons among studies because slightly different methods were used in each study (e.g. different lengths of counting time) and observer variability is inevitable between studies. Table 13 shows the average bird abundance and average species richness for the breeding bird studies that used point count methods. The highest average bird numbers were found in the Pothole Creek study.

Table 13: Abundance Comparisons Between Breeding Bird Studies Employing Count Circles

	Radius of count circle (meters)	Count time (minutes)	Average Abundance in grazed count circles	Average Abundance in ungrazed count circles	Average species richness in grazed count circles	Average species richness in ungrazed count circles
Pothole	50	15	20.1	37.6	11.1	17.0
Pekisko	100	10	21.0	25.7*	7.4	13.6*
S. Saskatchewan Leader	50	10	12.7	11.4	9.7	9.3
Oldman	50	15	17.3	33.7	17.0	24.3

*the Pekisko site was actually very lightly grazed, so it does not represent a truly ungrazed situation.

Although the average species richness per count circle was lower at Leader compared to Pothole and Oldman, the total species richness (including both grazed and ungrazed sites) was similar at all sites (Leader had 44 species, Oldman had 40 species, Pothole had 43 species).

Bird abundance and species richness were lower in the Leader study compared with the Oldman, Pekisko and Pothole studies. This may be in part due to differences in methods among studies. In the Pothole, Pekisko and Oldman studies each count circle was visited twice during the breeding season. When analyzing the data from these count circles, the maximum abundance and species richness across the two surveys were used. For example, if five singing yellow warblers were found in one count circle during the first visit and six were found in the second visit, six yellow warblers were used in the analyses. In the Leader study, the sites were only visited once during the breeding season. However, this difference probably only partly explains the lower numbers in the Leader study (e.g. at the ungrazed sites at Pothole Creek, the replicate surveys increased bird abundance by 23% and species richness by 22%). Another factor could be differences in point count duration; the Oldman and Pothole studies employed 15 minute counts compared to 10 minute counts used in the Pekisko and Leader studies. The longer count period may have added a few more birds, but the majority of bird observations were made in the first five to ten minutes and very few were added in the final five minutes.

Another difference between the riparian areas along the Oldman River and Pothole Creek and the South Saskatchewan is the species composition of the tree component of the forest. Along the South Saskatchewan, plains cottonwood (*Populus deltoids*) is the only poplar tree species. In the Oldman and Pothole systems there is a diverse hybrid mix of balsam poplar (*Populus balsamifera*), plains cottonwood (*Populus deltoids*) and narrow-leaved cottonwood (*Populus augustifolia*). Although at first it seems unlikely that this could influence bird abundance, research in Utah found that there were more bird nests in cottonwood hybrid zones compared to pure stands of single cottonwood tree species (Martinsen and Whitham, 1994). Three times as many bird nests were found in the hybrid zone compared to the single species zones. Within the hybrid forest, the hybrid trees contained twice as many bird nests as the parental species trees. The authors speculate that differences in tree architecture may account for the differences in nest distribution. Another factor may be food availability, as hybrid zones tend to be centers of insect species richness and abundance (Whitham, 1989).

5. Relationship of Findings to Other Studies in North America

Much of the early literature (1970's and 1980's) relating to biodiversity and riparian areas focused on quantifying the importance of riparian areas for birds (Gaines 1974, Carothers 1977, Hurst et al. 1980). More recently (1980's and 1990's) research has focused on the effects of disturbance on riparian birds, particularly grazing (Sedgwick and Knopf 1987, Schulz and Leininger 1991, Ammon and Stacey 1997). Discussed here are the most relevant studies on the influence of grazing on riparian biodiversity (primarily birds).

Saab et al. (1995) reviewed nine studies conducted in six states that studied the influence of livestock on birds in riparian areas. The authors evaluated both species and guilds to determine their vulnerability to grazing disturbances. Although there were a number of shortcomings with the quantitative data, they were able to find some consistent patterns and responses by many members of the riparian avifauna. In a qualitative assessment of all studies combined, they found that nearly 50% of the neotropical migrant landbirds decreased in abundance with grazing, 29% increased with grazing and 25% showed no clear response. Red-winged blackbirds, common yellowthroats and willow flycatchers were about 1.5 times more abundant in ungrazed treatments, indicating that these species are sensitive to changes resulting from livestock grazing. The authors also identified species that were likely to be negatively affected by grazing; these were yellow warbler, American redstart, gray catbird and yellow-breasted chat. American robin, killdeer and pine siskin showed the strongest trends towards increasing with grazing. Cavity-nesting species appeared to be the least affected by grazing. Species that are dependant on food resources produced by understory plants tended to be fewer in grazed compared to ungrazed treatments. These results from Saab et al. (1995) contain many similarities with the findings in this report. Here, I also found that red-winged blackbird, common yellowthroat, gray catbird and yellow warbler appear to be sensitive to livestock grazing. There are a number of differences between their findings and the results presented in this report: Here, brown-headed cowbirds decreased with grazing in all but one of the breeding bird studies, whereas Saab et al. reports increases in cowbirds with grazing in four out of five studies. It is possible that cowbirds are responding to variations in foraging opportunities adjacent to the riparian areas, rather than differences within the riparian areas. They may also be responding to differences in nest parasitism opportunities, which, in the Alberta studies seem to decrease with grazing (e.g. one of their main hosts, yellow warblers, decreases with grazing). Saab et al. reported increases in American robins with grazing, but in the Alberta/Saskatchewan studies robins decreased with grazing in two studies (Pothole and Pekisko), increased with grazing at Leader, decreased with grazing in the fall Oldman study and in the Oldman breeding bird study robins were almost equally abundant in the heavily grazed and ungrazed sites. These inconsistencies perhaps suggest that during the breeding season, robins are responding to a part of the riparian vegetation community that is not influenced by livestock grazing or are responding to differences in the adjacent uplands.

When individual studies comparable to those presented here are examined, there is considerable variation in how they are conducted and the degree of difference between "grazed" and "ungrazed" riparian areas. Much of the scientific literature does not describe the level of grazing beyond using the terms "grazed" and "ungrazed". These can mean very different things to different people and it makes it awkward to compare studies. For example, in a study by Kauffman et al. (1982), their grazed riparian site had been grazed for only two years for a period of 3 – 4 weeks each year. In Schulz and Leininger's (1991) study, their grazed riparian site was grazed annually for over fifty years.

Along the Bitterroot River in Montana, Mosconi and Hutto (1981) investigated bird communities in two study sites. One site was considered heavily grazed (2.5 cow-calf units per ha) from May to October for the past 30 to 40 years. The second site, referred to as ungrazed, was very lightly grazed (0.3 cow-calf units per ha) from May to September. The structural differences between their grazed and ungrazed sites, shown in photographs in their paper, appear similar to the structural differences observed in the Oldman River study. They found that the densities of 40% of the 43 bird species differed significantly between the sites. Nine of the affected species were obligate riparian birds species (e.g.; ruffed grouse, willow flycatcher, veery, common yellowthroat, northern oriole and song sparrow). Birds that had densities significantly greater on heavily grazed sites were: eastern kingbird, western wood pewee, house wren and American robin. There were no significant differences for yellow warblers or gray catbirds. Contrary to the results of the Alberta studies, total bird densities and species richness in the grazed and ungrazed sites were similar.

In Oregon, Taylor (1986) investigated nine sites with varying grazing histories in a willow-dominated riparian habitat. The site that was undisturbed by grazing for forty years had ten times as much shrub volume as the most heavily grazed areas. The undisturbed site also had 11 to 13 times as many birds as the heavily grazed sites and 5 to7 times as many birds as the sites that were heavily grazed up until 1980 (the surveys were conducted in 1981 and 1982). The ungrazed site had about 2.5 times as many species as the heavily grazed sites. Taylor also found significant positive relationships between shrub volume and relative bird abundance. Yellow warblers were found to be much more abundant in the ungrazed habitat, as were cedar waxwings, song sparrows, bobolinks, red-winged blackbirds, common yellowthroats, and northern orioles. The only bird that appeared to benefit from grazing was the killdeer. One of Taylor's sites had considerable shrub volume, but relatively few birds. This site was used by over 200 campers during the avian breeding season, suggesting that intensive human disturbance can have a considerable effect on riparian birds.

Crouch (1982) compared two cottonwood-willow riparian sites along the South Platte River in Colorado. One site was protected from grazing for 7 years and the other site had been "grazed by livestock at varying intensities". One of the unique aspects of this study is that Crouch not only measured wildlife on his study transects (which were visited 15 times over 2 years), but he also recorded cow observations, thereby gaining quantitative data on cattle densities. Of course, as he comments in his paper, it is not known if the cattle densities reflected long-term use rates. The other unique aspect of this study was that the data were collected over two entire years including the fall and winter seasons. Crouch found almost twice as many terrestrial birds on the ungrazed compared to the grazed site. Species that were more abundant in the ungrazed site included; northern flicker, barn swallow, blue jay, black-capped chickadee, brown thrasher, red-winged blackbird and dark-eyed junco. Species that were more abundant on the grazed site included; great horned owl, killdeer, American robin and western meadowlark. He also found that mule deer were five times more abundant on the grazed site and cottontail rabbits were seven times more abundant in the ungrazed site.

Also in Colorado, Schulz and Leininger (1991) looked at the avian response to cattle exclusion from previously heavily grazed willow-dominated riparian habitats. The grazed habitats were grazed annually by cattle from mid June to mid October. Three areas were excluded from grazing in the late 1950's. They found that the willow canopy cover was 8.5 times greater in exclosures. Bird species diversity and abundance was similar in the grazed areas and the exclosures, but they differed greatly in species composition. Wilson's warblers were significantly more abundant in the exclosures. Lincoln's sparrow and mountain chickadee were also more abundant in exclosures. American robins were more abundant in the grazed area. They concluded that livestock grazing changes habitat structure, resulting in a shift in the species composition of birds and small mammals in the montane riparian zone, while maintaining similar levels of diversity.

Krueper (1993) looked at a site in Arizona where cattle were removed from a woody riparian area. Within four years the understory and bank vegetation increased dramatically and highly significant density increases were seen in foliage insectivores such as the common yellowthroat and song sparrow.

An Oregon study looked at the influence of livestock grazing on a sedge-dominated riparian meadow (Dobkin et al. 1998). Again, two sites were examined, one that had been grazed for over thirty years (from May to October) and one that had been similarly grazed until four years before the study began. Bird species richness and abundance were greater on ungrazed plots in all three years of the study. There were almost twice as many birds in the ungrazed plots compared with the grazed plots. It should be noted that the riparian habitat in this study was not a woody habitat as in many of the other studies, but was a wet meadow, hence the relatively rapid vegetative and avian response to the removal of livestock grazing.

Although not looking at the effects of livestock grazing, McShea and Rappole (1999) investigated the effects on the bird community of excluding deer grazing from deciduous forest in Virginia. They found that bird populations increased following the exclosure of deer for 9 years. Deer densities outside of the exclosures were considered high (>25 deer/km^2). Similar to the riparian studies, they found that bird species that primarily used the forest floor and understory increased in response to the exclusion of deer grazing.

Several studies have found increases in bird abundance and richness with grazing in riparian areas. Medin and Clary (1990) found that species richness increased in grazed mountain riparian habitats in Idaho. There was no significant difference in abundance between the grazed and ungrazed site, but avian biomass in the grazed site (protected from grazing for 14 years) was almost twice that in the ungrazed site. At first this may seem contrary to the results found in the Alberta studies. However, looking more closely at Medin and Clary's study, the increase in species richness and biomass can be attributed to the introduction of large shorebirds (killdeer, willet and long-billed curlew) as a result of habitat alteration by grazing. They found that small mammal populations were almost a third higher on the grazed area than the ungrazed area, but that small mammal diversity was higher in the ungrazed habitat. It should also be noted that the riparian habitat in that study was a narrow mesic herbaceous zone along a mountain creek, very different from the tree and shrub dominated riparian zones in the Alberta and Saskatchewan studies.

A similar study in Nevada (Medin and Clary 1989) was unable to find differences between grazed and ungrazed (protected from grazing for 11 years) riparian habitats in total bird density, species richness, or species composition. They did find more structural variability in the shrub biomass component in the ungrazed habitat. Empidonax flycatcher, warbling vireo and MacGillivray's warbler were found in higher densities on the ungrazed plot. House wrens and song sparrows were more numerous on the grazed plot. In this case, the grazed site was grazed annually from mid-August to mid-November. The riparian habitat was a narrow strip along a mountain stream, dominated by aspen and willows.

Kauffman et al. (1982) compared the effects of a late season grazing regime and total exclusion from cattle grazing on birds and small mammals in a riparian zone dominated by black cottonwood and mixed conifers in Oregon. The grazed area was grazed starting in late August, for 3 - 4 weeks. They found little difference between grazed and ungrazed sites in breeding bird density, bird species diversity and species richness. They did find a significant reduction in small mammal use immediately after the three week grazing period. The grazed site in this study was very lightly grazed compared to the grazed sites used in the Alberta studies. Not only was it grazed for only 3 – 4 weeks in a year, the cattle also had access to adjacent meadows, which were apparently more heavily utilized than the forested riparian communities.

In Colorado, Sedgwick and Knopf (1987) looked at the impact of late fall to early winter grazing on breeding densities of migratory birds in a cottonwood forest. They established ten 16ha plots, five of which were controls (ungrazed) and five which were fenced and fall-grazed for 30 days(from October to November) for three years. They did not find any differences in the bird community between grazed and ungrazed sites and concluded that a seasonal, short-duration grazing system has no impact on breeding bird densities in cottonwood forests. They point out that common yellowthroats and yellow-breasted chats appear to be most sensitive to grazing and suggest that these species would be good indicators of grazing pressure. Again, the situation in this study is rather different from conditions in Alberta, where most riparian areas are grazed for considerably longer than 30 days a year, are grazed primarily during the plant growing season, and have been grazed annually for many more than three years. However it does suggest that light grazing can be conducted in riparian habitats that are initially healthy, resulting in few short-term impacts.

Ammon and Stacey (1997) took a different approach to investigating the influence of grazing on bird communities in a willow-dominated montane riparian community in Nevada. Their study area encompassed two sites, one grazed (24 cow-calf units in 30 ha from June to August) and one that had been rested from grazing for thirty years. They measured avian nest predation in each site and found that nest success (for both real and artificial nests) was lower on the grazed site. Of the above-ground nest, 83% were preyed upon on the grazed site compared with 36% on the ungrazed site. Of the ground nests, 67% were preyed upon on the grazed site compared to 43% on the rested site. The grazed site also had a significant reduction in streamside willow cover. Ammon and Stacey suggest that grazing reduces willow cover and thereby leads to greater predation rates by decreasing the availability of nest sites for riparian birds. They also suggest that structural differences result in higher incidental predation, changes in the composition of the predator assemblage or changes in predator search strategies.

In a recent study in cottonwood forests in Idaho, Saab (1999) examined the patterns of habitat use by breeding birds in riparian cottonwood forests. She evaluated habitat use at three spatial scales; microhabitat (local vegetation characteristics), macrohabitat (forest patch characteristics such as size, length and width) and landscape (surrounding land uses). She found that the best predictors of bird species richness were at the landscape level, particularly whether the cottonwood forest was adjacent to natural landscapes. Looking at individual species, Saab found that Swainson's thrush had the strongest relationship with natural landscapes and western wood pewees had the strongest relationship with agricultural landscapes (adjacent to the cottonwood forest). The yellow warbler had a strong positive relationship with large amounts of river and wetland vegetation.

Saab's study stimulates some interesting ideas about the influence of the surrounding landscape on riparian birds. This might explain why some species did not exhibit a clear response to grazing in the Alberta studies (e.g. American kestrel, eastern kingbird and American robin). In Saab's study, the American kestrel was strongly associated with cottonwood forests adjacent to natural habitats and the American robin was strongly associated with cottonwood forests adjacent to agricultural habitats. Yellow-breasted chats showed a strong positive relationship with the nearest cottonwood patch neighbour (i.e. more yellow-breasted chats in forests that were close to another cottonwood forest). With microhabitat variables, increasing willow densities were the most frequent significant predictor of species occurrence. Increased shrub cover and density were correlated with increases in the following species: American goldfinch, northern oriole, brown-headed cowbird, lazuli bunting, yellow warbler and yellow-breasted chat. Most of these are species that responded negatively to grazing (and removal of the shrub layer) in the Alberta studies. None of the Alberta or Saskatchewan studies measured variations in the surrounding landscape. Interestingly, in Alberta and Saskatchewan, it is often the ***ungrazed*** riparian areas that are surrounded by agricultural (cultivated) and urban landscapes. For example, in the Pothole Creek study, two of the three ungrazed sites were surrounded by cultivation. In fact, this is probably the underlying reason why the riparian area was not grazed; if the surrounding area was cultivated (within the same land parcel as the riparian area), extensive fencing would be required in order to graze the riparian area and keep cattle out of the crop. In the Oldman study, most sites were surrounded by natural landscapes for at least 100 to 500m out from the cottonwood forest because of the nature of the steep-sided coulees that flank the floodplain of the Oldman River. Saab's study reinforces the importance of considering not just the riparian area in isolation, but also the landscape around it. It also highlights the great significance of places like Suffield, which is one of few areas in the prairies where riparian areas are surrounded by large expanses of native landscapes.

In summary, the work that most closely mirrors the findings from the Alberta studies is that by Taylor (1986) and Crouch (1982), although the latter study did not make statistical comparisons. Both of these studies found similar decreases in bird abundance and richness as grazing intensity increased. Although other studies show no significant changes in overall bird abundance and species richness, they find that grazing disturbances cause significant shifts in the composition of the bird community as well as impacts on individual species (Mosconi and Hutto 1982, Medin and Clary 1990, Schulz and Leininger 1991). Most studies focus on comparing a grazed site with an ungrazed site. The degree of grazing intensity in "grazed" sites varies widely from study to study. The Pothole, Oldman and Suffield studies are in the minority in that they assess the influence of three different levels of grazing. In the literature reviewed, only Taylor (1986) looked at a continuum of grazing levels. Two studies reviewed here suggest possible mechanisms responsible for differences in bird abundance and richness. Ammon and Stacey (1997) found that avian predation rates are higher in grazed sites. Saab (1999) found that the habitat surrounding riparian habitats can be an important influence on the abundance of some bird species.

From the Alberta and Saskatchewan work synthesized here, the main contributions to the existing literature are:

1. Quantitative data on the influence of grazing on fall bird use of riparian areas (Saunders and Hurly 1999, Dale et al 1999). Ohmart (1996) notes that this is an area where quantitative research is lacking.
2. The influence of very light levels of grazing on riparian areas (Smith 1999) and different grazing regimes (covered to some extent in Dale et al. 1999).
3. The large magnitude of differences in the bird community between heavily grazed and ungrazed sites demonstrated in studies where replicates allow statistical analysis (as in Saunders and Hurly 2000b)
4. The effects of livestock grazing on tree health in riparian areas (Saunders and Hurly 2000a). There is information in the literature about the influence of grazing on tree regeneration (Glinski 1977), however no references were found regarding the influence of grazing on the vigour of existing trees.

6. General Discussion and Comparison of Results

6.1 Comparisons

Despite differences in methods between the six studies synthesized here, it is possible to glean some broad generalizations about the effects of grazing on biodiversity, particularly birds, in Alberta and Saskatchewan riparian systems (see section 6.2, following). The Suffield study was not designed specifically to test a grazing hypothesis, but none-the-less it parallels patterns observed in the Pothole, Pekisko and Oldman studies.

The Leader study was an anomaly amongst the six studies because it was the only study that did not find a difference in the bird communities between grazed and ungrazed sites. However, this study raises some interesting ideas about the influence of light grazing in riparian ecosystems and may provide some insight into the influence of very light grazing on riparian forests. Riparian landscapes have evolved with disturbance and where riparian forests experience no grazing (or other form of disturbance) for long periods of time, plant species diversity may decrease (similar to the situation in many temperate grassland communities and the mid-stages of forest succession), which may ultimately result in reduced bird species richness and abundance. Introducing light grazing into a mature riparian ecosystem may result in some openings in the shrub canopy and thereby introduce new plant and bird species. If this is the case, an important step in prescribing grazing in riparian areas would be to determine the successional stage. The stage could be established with the riparian vegetation classification key for Alberta (Thompson and Hansen, 2001).

Interestingly, although the ungrazed sites in the Oldman Study, which produced extremely high bird abundance and species richness, did not experience cattle grazing, they were all in urban areas and experienced other disturbances, such as trails, small fires and human activity (e.g. hikers, some light vehicle traffic). All sites experienced some level of browsing by deer. It is possible that urban riparian areas may experience increased deer browsing (because of reduced predation and hunting), which may stimulate plant diversity through browsing, but does not have the same impact on the shrubs as cattle. However, before conclusions on the role of light grazing in riparian ecosystems can be drawn, more data is required, especially more detailed information on grazing levels in the Leader study.

6.2 Dominant Themes and Consistent Messages

Eight dominant messages were developed, resulting from the review of Alberta and Saskatchewan studies:

1. High Intensities of Grazing Result in Reductions in Breeding Bird Abundance.
Four out of the five studies conducted during the breeding season found that breeding bird abundance decreased with increases in grazing intensity. With the exception of the Leader study, native bird abundance was between two and three times greater in ungrazed sites compared with heavily used sites. The Leader study did not show any significant difference between grazed sites and ungrazed sites. This is likely because the grazed sites appear to have been very lightly grazed compared to the grazed sites in the other studies, perhaps suggesting that light grazing in riparian zones may have minimal impact on bird abundance. It indicates that perhaps there is a threshold below which grazing does not impact vegetation structure, and hence biodiversity.

2. High Intensities of Grazing Result in Reductions in Breeding Bird Species Richness.
Bird species richness (number of species) decreased with increases in grazing intensities in all of the studies, except the Leader study. The meta-analysis using five studies shows that measures of species richness (all species and native species) respond negatively to increased grazing intensity across a broad geographic area in Alberta and into western Saskatchewan. In individual studies where species richness declined with grazing, approximately one quarter to one third fewer species were found in heavily used sites compared with ungrazed sites. The lack of response in the Leader study suggests that light grazing may have minimal impact on species richness.

3. There are Several Potential Indicator Species that Appear to be Sensitive to Grazing.
Some species responded to grazing in a consistent manner across all six studies. Bird species that rely on the shrub component of the riparian forest usually showed the largest reductions in numbers with increased grazing intensity. Breeding bird species that have potential as indicators of grazing effects in riparian systems in Alberta are least flycatcher, gray catbird, cedar waxwing, yellow warbler, common yellowthroat, red-wing blackbird and American goldfinch.

4. High Intensity Grazing Results in Reductions in Fall Bird Abundance and Species Richness
Only one study looked directly at the influence of grazing on fall bird abundance and species richness. The Oldman River fall study found that less than half as many birds used heavily grazed cottonwood forests compared to the ungrazed forests. Species richness also decreased with grazing intensity. The Suffield study included both spring and fall migrants and recorded decreases in native bird abundance and species richness with increased grazing. The importance of prairie riparian areas to migrating birds should not be understated. Although riparian forests support large numbers and diversities of breeding birds, there are very few species that rely solely on prairie riparian areas. However in the fall and spring, most boreal forest songbirds rely on riparian areas as stopover points during their flight across the prairies. Spring and fall migration periods are critical parts of avian lifecycles that can greatly influence population trends (Hutto, 1998).

5. High Intensity Grazing Results in Increases in European Starlings, a Non-native Species.

All of the breeding bird studies, except for the Leader study, showed increases in European starlings as grazing intensity increased. In the one fall study, European starlings were more abundant in the ungrazed sites. Starlings compete with native species for nest cavities, and therefore may negatively impact native bird communities. House Sparrows were not present in sufficient numbers in any of the studies to draw conclusions about their response to grazing.

6. Each Riparian System is Unique.

While there are some effects of grazing on bird communities common to all studies, it is clear that each system has inherent differences in how it responds to grazing. Some bird species responded quite differently to grazing in different riparian systems. For example, black-capped chickadees along the Oldman River were abundant in ungrazed sites but absent from heavily grazed sites. However in the Pothole Creek study chickadees were found only in grazed sites. In the Leader study, chickadees increased in abundance with grazing. Because riparian areas are inherently diverse, many factors other than grazing can influence riparian bird communities (e.g. plant species composition, tree density, influence of adjacent habitats, the presence of hybrid poplar trees, local hydrology and natural disturbances such as flooding and fire).

7. Ungrazed Benchmark Sites are Extremely Important

A common problem identified in several of the studies was the lack of ungrazed sites that could be used as benchmarks for comparing with grazed sites. Often the only ungrazed sites along a river or stream are those in urban areas (as was the case in the Oldman study). Obviously these areas currently experience other disturbances and many have experienced tremendous disturbance in the past (e.g. in the Oldman study, one of the ungrazed sites in Lethbridge was once heavily disturbed by mining and logging activities as well as intensive human settlement). Even within parks it is often difficult to find suitable benchmark sites because many parks (particularly provincial parks) allow cattle grazing in riparian areas. Riparian sites in Alberta and Saskatchewan that could serve as benchmarks should be identified and protected from human disturbances such as livestock grazing and recreational developments.

8. Appropriate Riparian Grazing Thresholds Have yet to be Defined

It is not possible from these studies to draw definite conclusions about the best grazing strategy and/or intensity to minimize impacts on riparian vegetation and birds. The results show that grazing through the entire growing season on an annual basis does impact bird populations quite dramatically, reducing riparian bird abundance by one half to one third of that in ungrazed areas. But if riparian areas are grazed, can they be grazed in such a way as to minimize impacts on biodiversity? Many people feel that the only solution is to completely protect riparian areas from grazing, as even short-term or seasonal use causes ecological damage (Davis 1982, Fleishner 1993, Belsky et al. 1999).

In terms of grazing strategies, one conclusion of the Alberta and Saskatchewan studies is clear; year-long or growing-season long grazing over many years appears to be particularly damaging to biodiversity in riparian zones. This kind of intensive use by livestock results in the loss of the shrub understory, which leads to large reductions in bird abundance and richness. The tree health data in the Oldman study suggests that intensive grazing over time may also lead to less healthy trees and presumably an acceleration of forest decline. The Oldman, Pothole and Suffield studies demonstrate that moderate levels of grazing (i.e. where cattle have access to the riparian zone for only part of the growing season) still impacts bird communities, but to a lesser degree than season-long grazing (Table 14). It is important to recognize that the effect of one season of grazing is not as important as the cumulative effect of heavy grazing and/or inappropriate timing applied chronically over many years.

Table 14: Variation in Native Bird Abundance* with no grazing, moderate grazing (for only part of the growing season) and high grazing (season-long)

	Nil	Moderate	High
Pothole Creek	49	34	24
Oldman River	129	72	60
Suffield	33.3	32.7	30.3

* for Pothole Creek and the Oldman River native bird abundance is given in number of birds per site (Pothole creek had 2 count circles per site, Oldman River had 4 count circles per site). For Suffield, encounter rates per hour are given and include both migrant and breeding birds.

The studies synthesized here suffer from the same lack of detailed information about grazing strategies as much of the U.S. research. This is primarily because the studies rely on information provided by livestock producers about how they manage cattle on their land. Although most landowners are very forthcoming with this information, their management techniques and cattle numbers often vary from year to year. Also, the impact of cattle on riparian zones varies from year to year depending on weather conditions and forage availability in the rest of the pasture. Hence, it is virtually impossible to quantify grazing pressure on riparian areas over time. Only in a carefully controlled long-term experimental situation would this kind of information be obtained.

Several researchers have attempted to recommend suitable grazing strategies for riparian areas. Clary and Webster (1989) suggested that short-term, early spring grazing may be preferable to summer grazing. Early season grazing can result in better distribution of livestock as upland vegetation is lush and attractive to cattle (Clary and Webster 1989, Platts 1991). Early season grazing may also allow riparian vegetation to re-grow and recover before the fall; Clary and Webster (1989) found that most browsing damage to willows occurred in later summer and fall. It is beyond the scope of this report to go into detail about different grazing strategies and how they might be used to avoid damage to riparian ecosystems. Literature that deals with alternative grazing strategies includes Davis (1982), Platts (1982), Platts (1991), Adams and Fitch (1995).

A general recommendation is that to avoid impacts on biodiversity riparian areas should be grazed lightly and only during those periods when the least amount of damage will be done to the shrub community. Because complete removal of livestock from riparian areas is impractical and uneconomical for most producers, the focus of stewardship programs should be on protection and maintenance of the current condition of healthy riparian areas and restoration of heavily impacted riparian areas. Some prescriptions for restoration include the following (Adams and Fitch 1995):

1. Resting the riparian area for several seasons to allow woody species to regenerate and become grazing resistant. This can be accomplished with temporary fencing, including electric fencing.
2. Balancing livestock numbers with the available forage resources on an annual basis versus applying the same cattle densities each year.
3. Improving the distribution of livestock (e.g. by using salt and waterers to attract livestock away from sensitive areas).
4. Using riparian pastures with management tailored to woody species regeneration.

7. Recommendations

7.1 Recommendations for Future Research

1. Additional studies on the influence of grazing on bird populations

Although some definite generalizations can be made about the impacts of grazing on biodiversity across the six studies, there are also differences in response to grazing unique to each study. Additional research conducted in different riparian areas across Alberta and Saskatchewan would have some value and likely yield some new information.

Of the studies synthesized here, four were conducted in poplar-dominated forests (Suffield, Oldman, Pekisko and Leader). It would be valuable to determine if similar trends are found in narrower riparian systems in drier shrub-dominated areas such as along small prairie creeks and in the wetter environments of parkland Alberta.

If these studies are to be used in stewardship programs, livestock producers may pay more attention to the results of local studies versus those from another part of the province. So, although repeat studies may have less value among the scientific community, they could have considerable value in helping local producers make better decisions regarding their riparian grazing strategies.

As finding appropriate ungrazed or benchmark sites can be challenging, priority areas for additional study should be based on the existence of benchmark sites (preferably more than one along the same reach) and a range of grazing intensities and strategies. Suggestions for improving the methodologies of riparian grazing studies are given in section 7.9.

Where biodiversity studies are being conducted for inventory purposes, it is important to factor in the effect of landuse, such as grazing management, where possible. Increased understanding of the effects of landuse practices on biodiversity will lead to improved understanding of practices that maintain biodiversity and allow those practices to be applied over a broader landscape.

2. Conduct riparian health assessments in conjunction with biodiversity studies

In this report, the relationship between riparian health assessments and biodiversity was examined using one data set (Pothole Creek). It would be useful to further test and refine the relationships by incorporating other study sites. A priority should be the Oldman River study sites as detailed vegetation data, breeding bird data and fall bird data already exist for these sites. It would also be useful to conduct riparian health assessments at the Leader sites to gain a better understanding of grazing intensities and riparian health in that area.

3. Investigate the mechanisms behind the effect of grazing on riparian biodiversity

By understanding the mechanisms that result in biodiversity losses due to grazing, it may be possible to ultimately improve grazing strategies. Very limited work has been done in this area, but Ammon and Stacey's (1997) look at predation rates was the type of research needed. It is known that grazing negatively influences bird communities and there are ideas for why this might be, but there is a lack of quantitative data to support these hypotheses. Research that investigates, in detail, the relationships and processes occurring in riparian bird communities are required. Considering the variation in cowbird response to grazing between the studies in Alberta and others in North America (Saab et al. 1995) and the effect of cowbirds on songbird populations, this would be a valuable area of research. In Alberta, a research project is being initiated this year that will look at nesting success and productivity in some key riparian bird species (e.g. yellow warblers and house wrens) in the ungrazed, moderately grazed and heavily grazed sites along the Oldman River.

4. Investigate cattle behaviour in riparian zones

A few studies have looked at cattle foraging behaviour, but most of this research has been done in mountain and foothills environments (Gillen et al. 1985, Marlow and Pogacnik 1986). As prairie poplar-dominated forests are frequently used for cattle grazing in Alberta and Saskatchewan, research into how cattle use cottonwood forests, their grazing and browsing preferences, seasonal differences in foraging behaviour and the actual physical and biological mechanisms that cause reductions in shrub communities would be valuable. Such research could ultimately be used to develop better riparian grazing management strategies and strengthen stewardship messages.

5. Conduct research on the influence of grazing on other aspects of riparian biodiversity

The six studies summarized here, as well as most of the published literature, focus on breeding bird communities because breeding birds are relatively easily measured and they are usually a good indicator of overall biodiversity (Bock and Webb, 1984). In the United States, a few studies have looked at the influence of grazing on small mammal populations (Medin and Clary 1989, Schultz and Leininger 1991); one study looked at the influence of grazing on garter snake populations (Szaro et al. 1995), and several studies have focused on fish populations (Marcuson 1977, Li et al. 1994, Knapp and Matthews 1996). Except for the pilot project described in this report, most studies on invertebrates in riparian areas have focused on aquatic invertebrates (Rinne 1988, Strand and Merritt 1999).

To gain a better understanding of how grazing influences biodiversity, and perhaps the mechanisms behind the effects on breeding bird populations, it would be valuable to conduct studies in Alberta and Saskatchewan into the effect of grazing on mammals, invertebrates, reptiles and amphibians. Further invertebrate work, in particular, may provide insight into the mechanisms behind changes in the bird populations resulting from grazing. The most efficient approach to expanding biodiversity studies would be to use riparian sites with existing information (e.g. the Oldman River sites where detailed vegetation and bird data have been collected).

6. Conduct further research on the influence of grazing on seasonal biodiversity of riparian areas

The majority of studies have focused on breeding season use of riparian areas. Obviously riparian areas are important to biodiversity at all times of the year. As the Oldman River fall study demonstrated, grazing can influence bird abundance and richness in migratory periods as well. It would be useful to have information on winter and early spring use of riparian areas and how this is influenced by grazing intensity.

7.2 Stewardship-based Recommendations and Messages

1. To avoid impacts on riparian biodiversity, livestock producers need to graze riparian areas lightly and only during periods of time when the least amount of damage is done to the shrub community. Recommendations on exact timing and duration of grazing cannot be made based on the information in this report, but the studies discussed here suggest that season-long grazing has significant impacts on riparian biodiversity. It is likely that prescriptions for appropriate grazing management will differ somewhat from system to system, depending on the ecological and physical characteristics of each riparian area.

2. Stewards of riparian areas, both livestock producers and others, can use indirect measures of biodiversity to evaluate the health of their riparian areas. The shrub community, especially shrub volume appears to be a good indirect measure of biodiversity, as demonstrated by several of the studies and the correlations between riparian health assessments and bird studies. The shrub community is also easier for non-biologists to measure versus monitoring bird or other wildlife populations.

3. A riparian area with a healthy shrub community and high biodiversity is also a reliable and economically sustainable resource for livestock producers. When a riparian area is grazed intensively, biodiversity is lost and the very components that make it attractive to cattle and producers start to disappear as well. As the Oldman study showed, intensive grazing over time appears to accelerate the aging and death of cottonwood trees, ultimately leading to the premature loss of trees, and thus the shade and other benefits they provide to livestock and producers. Although the exact mechanism for declining tree health as a result of grazing is not known, it may be directly related to the loss of the shrub community and the resulting warmer, drier environment. In many riparian ecosystems, once the shrub component is removed, it rarely recovers, even with the removal of cattle grazing (Fleischner 1994, Ohmart 1996).

7.3 Other Recommendations

1. Where appropriate, publish the Alberta and Saskatchewan studies in scientific journals Obviously this is up to the researchers themselves, but it is clear from this synthesis that the six studies presented here provide information that supports existing research and in some cases provides new information. One of the interesting things that becomes apparent when viewing the literature is that there are almost as many review papers (Skovlin 1984, Kauffman and Krueger 1984, Fleischner 1994, Saab et al. 1995, Ohmart 1996, Belsky et al. 1999) published as there are original research papers published.

2. Identify and protect riparian benchmark sites. Although broad-scale riparian conservation is not the focus of this report, most of the studies identified difficulty in finding appropriate ungrazed or benchmark sites. For example, the Leader study had 10 ungrazed count circles compared to 26 grazed count circles, the Suffield study only had one ungrazed site (Sherwood Forest), and the

ungrazed site in the Pekisko study was actually very lightly grazed by cattle. Most of the studies found that the ungrazed riparian areas were found to support almost twice as many breeding birds as heavily used sites. Therefore, it is important that remaining ungrazed riparian areas be identified and protected.

7.4 Suggestions for Investigating the Influence of Grazing on Riparian Areas

This report raised a number of methodological problems in the six studies, and in similar studies reported in the literature. Recommendations for conducting research into grazing influences on biodiversity in riparian areas include:

1. Define grazing levels as quantitatively as possible to develop a clear index of grazing intensity (use over time). Consider also measuring cattle use in an objective manner (e.g. sampling cattle use), although this will only indicate recent use and not long-term history. Seek the assistance of the range community in better defining grazing use levels and in standardizing approaches and reporting of grazing intensities in order to make better comparisons between studies of grazing related effects.
2. If conducting breeding bird surveys, consider additional surveys earlier in the breeding season (e.g. mid-May) to gain better information on early-season nesters such as woodpeckers and starlings.
3. Ensure adequate replication for statistical analyses of results and comparison with other studies.
4. Where possible, use sites representing a continuum of grazing intensities and/or strategies rather than simply comparing a grazed site with an ungrazed site.
5. Collect quantitative information on surrounding landuses and riparian patch size for inclusion in data analyses.
6. To allow comparison among similar studies in the future, record bird count data in five minute intervals, regardless of the total length of the count period (e.g. 10 minutes or 15 minutes).

8. Conclusions

The six studies summarized indicate effects on biodiversity with increased grazing. Five of the six studies show livestock grazing negatively impacts bird communities. One showed a slight, but statistically insignificant, increase in bird abundance and species richness with light grazing.

Some relationships were found between the Cows and Fish Program's riparian health assessments and bird community variables. The strongest relationships were with components of the shrub community. The measure with the most potential to predict the bird community is shrub volume (calculated by summing the height of each shrub layer by its percent cover).

A data meta-analysis using five of the studies revealed a significant effect of grazing on species richness across a broad geographic range including Alberta and western Saskatchewan. Some bird species showed similar negative trends across all or most studies, suggesting that they are good indicators of grazing pressure.

The following six priorities for future research were recommended:

1. Conduct additional studies on the influence of grazing on bird populations in other riparian areas, especially those that are structurally different from the studies in this report (e.g. shrub-dominated prairie creeks, parkland riparian zones).
2. Conduct riparian health assessments in conjunction with biodiversity studies. Priorities for riparian health assessments should be those areas where bird data has already been collected (e.g. the Leader sites and Oldman River sites).
3. Investigate the mechanisms behind the effect of grazing on riparian biodiversity (e.g. predation rates, nest site availability, foraging opportunities).
4. Investigate cattle behaviour in riparian zones (e.g. grazing and browsing preferences in cottonwood forests and seasonal differences in foraging behaviour).
5. Conduct research on the influence of grazing on other aspects of riparian biodiversity (e.g. invertebrates and small mammals).
6. Conduct further research on the influence of grazing on seasonal biodiversity of riparian areas (e.g. winter bird use).

Of the research recommendations given above, priority should be given to those that will actually benefit stewardship activities and ultimately result in improved riparian grazing management. Recommendation 1 should include studies in areas where livestock producers need local data on the effect of grazing on riparian biodiversity or where the riparian environment differs greatly from those used in previous studies. Recommendation 2 may improve understanding among landowners of the link between riparian health and biodiversity, and allow non-biologists to monitor riparian biodiversity through this indirect measure. Recommendations 3 and 4 are especially important as they may provide insight into developing appropriate grazing prescriptions that reduce the negative impacts of grazing. Although important scientifically, recommendations 5 and 6 likely will have less direct and immediate relevance for stewardship programs.

Based on the data in this report, it is not possible to recommend specific grazing prescriptions for reducing impacts on biodiversity, although it appears that to protect biodiversity, grazing in riparian areas should not be season-long and should take place at times when impact on the shrub community is minimized.

Riparian biodiversity is important to landowners and livestock producers because a diverse riparian area is a healthy riparian area. In turn, a healthy riparian area is a reliable riparian area. Reliable, in that it provides immediate benefits such as shade, water and forage for livestock as well as long-term, wide-ranging benefits such as flood protection, raised water tables, and improved water quality and quantity. If a riparian area is grazed intensively over time, not only does it experience losses of biodiversity, but it also becomes a less reliable and sustainable resource and the long-term impacts can be far-reaching.

9. Personal Communications

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Appendix A: Location of Study Sites

Note: Not all study site locations could be included in this report because of confidentiality agreements with landowners.

South Saskatchewan, Estuary - Leader

Count Circle	Latitude			Longitude		
	degrees	minutes	seconds	degrees	minutes	seconds
E01 (G)	50	56	56	109	46	5
E02	50	57	1	109	46	25
E03	50	57	8	109	46	51
E04	50	57	5	109	48	32
E05	50	56	48	109	48	11
E06 (U)	50	57	3	109	43	55
E07 (U)	50	57	24	109	43	11
E08	50	57	24	109	42	38
E09	50	57	42	109	42	27
E10	50	58	2	109	42	43
E11	50	56	38	109	48	32
E12	50	56	32	109	48	9
E13	50	56	15	109	45	47
E14	50	56	15	109	45	16
E15	50	56	12	109	44	52
E16	50	55	30	109	52	12
E17	50	57	26	109	43	40
E18	50	57	49	109	43	27
L01	50	59	14	109	24	1
L02	50	59	8	109	24	21
L03 (U)	50	58	59	109	24	44
L04 (U)	50	58	53	109	25	0
L05 (U)	50	58	46	109	25	26
L06 (U)	50	58	36	109	25	59
L07 (U)	50	58	30	109	26	23
L08 (U)	50	58	23	109	26	46
L09 (U)	50	58	13	109	27	1
L10 (U)	50	57	59	109	28	27
L11	50	58	30	109	32	0
L12	50	58	30	109	31	54
L13	50	58	5	109	31	31
L14	50	58	43	109	34	19
L15	50	58	17	109	34	13
L16	50	58	54	109	35	47
L17	50	59	4	109	36	43
L18	50	59	9	109	37	27

South Saskatchewan, Suffield

Site	UTM Coordinates	
	Northing	**Easting**
Sherwood Forest	5590600	531000
Bullpen	5567200	526500
Dugway	5573800	526600
Riverbend Woods	5564900	526600

Appendix B: Species Recorded in Alberta/Saskatchewan Riparian Studies

Notes: Species labeled with "AQ" (aquatic) in the guild column were excluded from the analyses because they were associated with the river rather than the riparian area directly. All studies recorded "northern oriole", they were assumed to all be Baltimore orioles and have been recorded as such, although though some of them may have been Bullock's orioles.

Key: AQ=Aquatic, ca= carnivorous, om=omnivorous, gi=ground insectivore, fi=foliage insectivore, ai=aerial insectivore, bi=bark insectivore

Species	Code	Foraging Guild	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Common Loon	COLO	AQ					x	
Horned Grebe	HOGR	AQ					x	
Red-necked Grebe	RNGR	AQ					x	
Western Grebe	WEGR	AQ					x	
American White Pelican	AWPE	AQ					x	
Double-crested Cormorant	DCCO	AQ					x	
Great Blue Heron	GBLH	AQ					x	
Trumpeter Swan	TMSW	AQ					x	
Canada Goose	CAGO	AQ					x	
Gadwall	GADW	AQ					x	
American Wigeon	AMWI	AQ					x	
Mallard	MALL	AQ			x	x	x	x
Blue-winged Teal	BWTE	AQ				x	x	
Cinnamon Teal	CITE	AQ					x	
Northern Shoveler	NOSV	AQ					x	
Northern Pintail	NOPI	AQ					x	
Green-wing Teal	GWTE	AQ					x	
Canvasback	CANV	AQ					x	
Lesser Scaup	LESC	AQ					x	
Common Goldeneye	COGO	AQ					x	
Barrow's Goldeneye	BAGO	AQ			x			
Common Merganser	COME	AQ					x	
Red-breasted Merganser	RBME	AQ					x	
Osprey	OSPR	ca					x	
Bald Eagle	BAEA	ca					x	
Northern Harrier	NOHA	ca	x			x	x	
Sharp-shinned Hawk	SSHA	ca		x			x	
Cooper's Hawk	COHA	ca	x	x			x	
Broad-winged Hawk	BWHA	ca					x	
Swainson's Hawk	SWHA	ca	x	x			x	
Red-tailed Hawk	RTHA	ca	x	x	x	x	x	
Ferruginous Hawk	FEHA	ca					x	
American Kestrel	AMKE	ca	x	x	x	x	x	
Merlin	MERL	ca		x			x	
Prairie Falcon	PRFA	ca					x	
Gray Partridge	GRPA	om					x	
Ring-necked Pheasant	RGNP	om	x			x	x	x
Sharp-tailed Grouse	STGR	om					x	
Ruffed Grouse	RUGR	om			x			

Species	Code	Foraging Guild	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Sora	SORA	gi				x	x	
American Coot	AMCO	AQ					x	
Killdeer	KILL	gi					x	
American Avocet	AMAV	AQ					x	
Greater Yellowlegs	GRYE	AQ					x	
Lesser Yellowlegs	LEYE	AQ					x	
Solitary Sandpiper	SOSA	AQ					x	
Willet	WILL	AQ					x	
Spotted Sandpiper	SDSA	gi			x	x	x	x
Upland Sandpiper	UPSA	gi					x	
Long-billed Curlew	LBCU	gi						x
Marbled Godwit	MAGO	AQ					x	
Common Snipe	COSN	gi			x	x	x	
Ring-billed Gull	RBGU	AQ					x	
Common Tern	COTE	AQ					x	
Rock Dove	RODO	gi					x	
Mourning Dove	MODO	gi	x	x	x	x	x	x
Black-billed Cuckoo	BBCU	fi					x	x
Great Horned Owl	GHOW	ca	x	x			x	
Long-eared Owl	LEOW	ca					x	
Common Nighthawk	CONI	ai					x	x
Belted Kingfisher	BEKI	ca					x	
Yellow-bellied Sapsucker	YBSA	bi	x				x	
Red-naped Sapsucker	RNSA	bi			x		x	
Downy Woodpecker	DOWO	bi	x	x		x	x	
Hairy Woodpecker	HAWO	bi	x	x	x		x	
Northern Flicker	NOFL	om	x	x	x	x	x	x
Pileated Woodpecker	PIWO	bi				x	x	
Olive-sided Flycatcher	OSFL	ai				x	x	
Western Wood Pewee	WWPE	ai	x	x	x	x	x	x
Alder Flycatcher	ALFL	ai			x	x	x	
Least Flycatcher	LEFL	ai	x	x	x	x	x	x
Say's Phoebe	SAPH	ai					x	
Western Kingbird	WEKI	ai	x	x		x	x	x
Eastern Kingbird	EAKI	ai	x		x	x	x	x
Loggerhead Shrike	LOSH	ca					x	
Blue-headed Vireo	BHVI	fi					x	
Cassin's Vireo	CAVI	fi			x		x	
Philadelphia Vireo	PHVI	fi		x			x	
Warbling Vireo	WAVI	fi	x	x	x	x	x	x
Red-eyed Vireo	REVI	fi	x	x	x	x	x	x
Blue Jay	BLJA	om					x	x
Black-billed Magpie	BBMA	om	x	x	x	x	x	x
American Crow	AMCR	om	x			x	x	x
Common Raven	CORA	om			x		x	
Horned Lark	HOLA	gi					x	x

Species	Code	Foraging Guild	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Tree Swallow	TESW	ai	x		x	x	x	
Violet-green Swallow	VGSW	ai				x	x	
N.Rough-winged Swallow	NRWS	ai					x	
Bank Swallow	BKSW	ai					x	
Cliff Swallow	CLSW	ai					x	
Barn Swallow	BRSW	ai				x	x	
Black-capped Chickadee	BCCH	fi	x	x	x	x	x	x
Red-breasted Nuthatch	RBNU	bi	x	x	x		x	
White-breasted Nuthatch	WBNU	bi	x	x			x	
Brown Creeper	BRCR	bi					x	
House Wren	HOWR	fi	x	x	x	x	x	x
Marsh Wren	MAWR	fi				x	x	
Ruby-crowned Kinglet	RCKI	fi		x			x	
Golden-crowned Kinglet	GCKI	ai		x			x	
Mountain Bluebird	MOBL	gi	x	x			x	
Townsends Solitaire	TOSO	ai					x	
Veery	VEER	gi	x				x	x
Gray-cheeked Thrush	GCTH	gi					x	
Swainson's Thrush	SWTH	gi		x			x	
Hermit Thrush	HETH	gi					x	
American Robin	AMRO	gi	x	x	x	x	x	x
Gray Catbird	GRCA	fi	x	x	x	x	x	x
Brown Thrasher	BRTH	gi	x	x	x	x	x	x
European Starling	EUST	gi	x	x	x	x	x	x
American Pipit	AMPI	gi					x	
Sprague's Pipit	SPPI	gi					x	
Cedar Waxwing	CEWX	fi	x	x	x	x	x	x
Tennessee Warbler	TEWA	fi					x	
Orange-crowned Warbler	OCWA	fi		x			x	
Yellow Warbler	YEWB	fi	x	x	x	x	x	x
Yellow-rumped Warbler	YRWA	fi		x			x	
Townsends Warbler	TOWA	fi		x				
Palm Warbler	PAWA	fi					x	
Blackpoll Warbler	BPWA	fi		x			x	
Black and white Warbler	BAWW	fi		x			x	
American Redstart	AMRE	fi		x			x	
Ovenbird	OVEN	gi		x			x	
Northern Waterthrush	NOWA	gi		x	x		x	
MacGillivray's Warbler	MGWA	fi		x			x	
Common Yellowthroat	COYE	fi	x	x		x	x	x
Wilson's Warbler	WIWA	fi		x			x	
Yellow-breasted Chat	YBCH	fi					x	x
Western Tanager	WETA	fi			x			
Spotted Towhee	RSTO	om		x			x	x
American Tree Sparrow	ATSP	gi					x	
Chipping Sparrow	CHSP	om		x			x	

Species	Code	Foraging Guild	Oldman River Breeding	Oldman River Fall	Pekisko Creek	Pothole Creek	S. Sask Suffield	S. Sask Leader
Clay-coloured Sparrow	CCSP	gi	x	x	x	x	x	x
Vesper Sparrow	VESP	om				x	x	x
Lark Sparrow	LASP	om					x	x
Lark Bunting	LKBU	om					x	
Savannah Sparrow	SASP	om					x	
Fox Sparrow	FOSP	om					x	
Song Sparrow	SOSP	gi	x		x	x	x	
Lincoln's Sparrow	LISP	om	x	x	x		x	
Swamp Sparrow	SWSP	om					x	
White-throated Sparrow	WTSP	om		x			x	
Harris' Sparrow	HASP	om					x	
White-crowned Sparrow	WCSP	om		x			x	
Dark-eyed Junco	DEJU	om		x			x	
Rose-breasted Grosbeak	RBGR	om					x	
Black-headed Grosbeak	BHGR	om	x					
Lazuli Bunting	LZBU	om						x
Bobolink	BOBO	fi						x
Red-winged Blackbird	RWBL	om	x			x	x	
Western Meadowlark	WEME	gi				x	x	x
Yellow-headed Blackbird	YHBL	om				x	x	
Brewer's Blackbird	BRBL	om	x		x		x	x
Common Grackle	COGR	om					x	
Brown-headed Cowbird	BHCO	gi	x		x	x	x	x
Baltimore Oriole	BAOR	om	x	x	x	x	x	x
Purple Finch	PUFI	om					x	
Red Crossbill	RECR	om					x	
White-winged Crossbill	WWCR	om	x				x	
Pine Siskin	PISI	om		x	x		x	x
American Goldfinch	AMGO	om	x	x	x	x	x	x
House Sparrow	HOSP	om	x		x	x	x	x

Appendix C: Riparian Health Assessment Inventory Form
(as used by the Cows and Fish Program)

From The University of Montana Riparian and Wetland Research Program, http://www.rwrp.umt.edu/

RWRP LOTIC INVENTORY FORM

Record ID No: ________________

ADMINISTRATIVE DATA

A1. Field data collected by: ________________

A2. Funding Agency/Organization: ________________

A3a. BLM State Office: ________________

A3b. BLM Field Office/Field Station: ________________

A3c. BLM Office Code: __________ **A3d.** Is the polygon in an active BLM grazing allotment? (Yes; No; NA): __________

If **Yes**, **A3e:** GABS Allot. No: ________ GABS ID: ________ GABS Allotment Name: ________ GABS Mgmt. Status: ______

A3f: GABS Allot. No: ________ GABS ID: ________ GABS Allotment Name: ________ GABS Mgmt. Status: ______

A4. USFWS Refuge: ________________

A5. Reservation: ________________

A6. NPS Park/NHS: ________________

A7. USFS National Forest: ________________

A8. Other Location: ________________

A9. Year: ______ **A10.** Date field data collected: __________ **A11.** Observers: ________________

A12a. At least some part of this polygon has been inventoried more than once (resampled)? (Yes; No): __________

If **Yes**, **A12b.** This polygon coincides exactly with another inventoried polygon? (Yes; No): ______

A12c. Is this the latest inventory for this polygon? (Yes; No): ________

A12d. ID No.(s) of other inventories of this polygon: ________________

A12e. Other years: __________ **A12f.** This polygon shares common area with other inventoried polygon(s)? (Yes; No): ______

A12g. Other years: ________________

A12h. ID No.(s) of other records sharing area with this polygon: ________________

A13a. Has a change in management occurred? (Yes; No): ______ If **Yes**, **A13b.** Year that changed occurred: __________

A13c. Type of management change applied:

____

____

____

____

____

LOCATION DATA

B1. State/Province: __________ **B2.** County/Municipal District: ________________

B3. Allotment/Range Unit: ________________

B4. Area name: ________________ **B5.** Polygon No.: __________

B6. Location: 1/4 1/4 Sec: __________ 1/4 Sec: __________ Sec: __________

Township (NS): __________ Range (EW): __________ **B7.** Elev. (ft): ______ ; (m): ______

B8a. Hydrologic unit code (HUC): __________ **B8b.** Sub-basin name (4th level HUC): __________

B8c. Sub-basin (sq mi): __________ ; (sq m): __________ **B8d.** Sub-basin (ac): __________ ; (hect): __________

B8e. Sub-basin perimeter (mi): __________ ; (m): __________

B9a. UTM coordinates of polygon UPPER END: Easting: __________; Northing: __________ ; Zone: ______

B9b. UTM coordinates of polygon LOWER END: Easting: __________; Northing: __________ ; Zone: ______

B9c. UTM coordinates of any other point of interest in the polygon: East: __________ ; North: __________; Zone: ______

B9d. GPS Unit #: __________ WPt Upper: __________ WPt Lower: __________ WPt Other: __________

B9e. Comments: ________________

B10. Quad map(s): ________________ ________________

SELECTED SUMMARY DATA

Record ID No: ____________

C1. Wetland type: ________________ **C2.** Polygon size (acres):________ ; (hect): ________

C3a. Is the entire polygon an upland? (Yes; No): ______ If **No, C3b.** Does the polygon consist entirely of functional wetland types? (Yes; No): _____ **C3c.** Functional wetland (acres):______ ; (hect): ______ **C3d.** Percent of total polygon: ______

C4. Does the polygon contain a defined streambank or channel? (Yes; No): ______

C5. Channel length (mi): ______ ; (km): ______ **C6.** Number of river miles the polygon represents: (mi) ______ ; (km): ______

C7a. Was the Pfankuch rating used? (Yes; No): ______ If **Yes, C7b.** Pfankuch Score: ______

Health Assessment Summary

C8. Polygon Health:

	Rating Percent (%)	Descriptive Category:
Vegetation:	______	______________________
Soil / Hydrology:	______	______________________
Overall:	______	______________________

Rating Percent Range	***Descriptive Category***
80-100	***Proper Functioning Condition (Healthy)***
60-79	***Functional At Risk (Healthy, but with Problems)***
<60	***Nonfunctional (Unhealthy)***

VEGETATION DATA

D1a. Wetland prevalence index: ______

D1b. Vegetation structural diversity: ______________________

Trees

D2a. Are trees present? (Yes; No): ______

D2b. Tree species by canopy cover (%) and percent age group (%)

SPECIES	COV (%)	SDLG/DEC	SPLG/DEC	POLE/DEC	MAT/DEC	DEAD

SPECIES	**D3.** Regeneration Category	**D4.** Age Group Distribution Category	**D5.** Seedling/Sapling Utilization

Shrubs

Record ID No: ______________

D6a. Are shrubs present? (Yes; No): ______

D6b. Shrub species canopy cover (%), age/size groups (%), and utilization

Shrub util. not coll. prior to 1990

Not collected prior to 1991

SPECIES	COV (%)	SDLG-SPLG/UTIL	MATURE/UTIL	DEC-DEAD/UTIL	**D6c.** Shrub Growth Form (N,F,U)

D7. Graminoids

Graminoids present?
(Yes; No): ________

SPECIES	COV (%)

D8. Forbs

Forbs present?
(Yes; No): ________

SPECIES	COV (%)

Record ID No: ______________

D9. Plant Group by Canopy Cover (%)

Layer	Trees	Shrubs	Graminoids	Forbs
3 (>6.0 ft):				
2 (>1.5 - 6.0 ft):				
1 (0 - 1.5 ft):				

D10. Total canopy cover (%) by lifeform:

Trees: __________ Shrubs: __________

Graminoids: __________ Forbs: __________

D11. Total canopy cover (%) by woody species: ________

D12. Total canopy cover (%) by all plant lifeforms: ________

Weed Data

D13a. Are invasive species present ? (Yes; No; NC) ________

If **Yes**, **D13b.** The portion (%) of the polygon ***infested*** by each of the following invasive species:

Canada Thistle:		Leafy Spurge:	
Common Hound's-tongue:		Purple Loosestrife:	
Common Tansy:		Sulphur Cinquefoil:	
Dalmatian Toadflax:		Russian Olive:	
Diffuse Knapweed:		Saltcedar (Tamarisk):	
Spotted Knapweed:		Scotch Thistle:	
Russian Knapweed:		Dyer's Woad:	
Whitetop:		St. John's Wort:	
Others:			
Others:			
Others:			

D13c. What percent (%) of the polygon is ***infested*** by all invasive weeds? ________

D14. Habitat Types and Community Types Record ID No: ______

Classification Type Name	Phase	Percent of Polygon	Successional Stage or Comments

D15a. Are undesirable herbaceous species present? (Yes; No; NC): ______ *Not collected prior to 1991*

If **Yes, D15b.** Record the combined canopy cover (%) of all undesirable herbaceous species observed: ______

D16. Polygon trend: Improving, Degrading, Static, or Status Unknown? ______

D17. Explain trend description and give other vegetation comments:

WATER QUALITY DATA (TMDL DATA)

Record ID No: __________

E1. Waterbody number: __________

E2a. Is the waterbody a 303(d) listed impaired stream? (Yes; No) ______

If **Yes, E2b.** Year of listing? ______

E3. Waterbody TMDL priority: __________

E4. TMDL development status: __________

E5. Probable cause(s):

E6. Probable impaired uses:

E7. Probable source(s):

PHYSICAL SITE DATA

F1. Does the polygon contain a stream bank or channel bottom? (Yes; No; NC): ______ If **No,** go to item **F17a.**

F2a. Is the channel bottom visible? (Yes; No; NC): ______ *Not collected prior to 1990, and part of 1991*

If **Yes, F2b.** Give the percent (%) of each size (must approx. 100%):

- ______ >20 inches (Medium Boulders +)
- ______ 10 - 20 inches (Small Boulders)
- ______ 5 - 10 inches (Large Cobbles)
- ______ 2.5 - 5 inches (Small Cobbles)
- ______ 0.6 - 2.5 inches (Coarse Gravel)
- ______ 0.08 inches - 0.6 inches (Fine Gravel)
- ______ 0.062 mm - 2 mm (Sand)
- ______ <0.062 mm (Silt and Clay)

F3a. Are bank materials present? (Yes; No; NC): ______ *Not collected prior to 1990, and part of 1991*

If **Yes, F3b.** Give the percent (%) of each size (must approx. 100%):

- ______ >20 inches (Medium Boulders +)
- ______ 10 - 20 inches (Small Boulders)
- ______ 5 - 10 inches (Large Cobbles)
- ______ 2.5 - 5 inches (Small Cobbles)
- ______ 0.6 - 2.5 inches (Coarse Gravel)
- ______ 0.08 inches - 0.6 inches (Fine Gravel)
- ______ 0.062 mm - 2 mm (Sand)
- ______ <0.062 mm (Silt and Clay)

F4a. Is there active lateral cutting of stream? (Yes; No; NC): ______

If **Yes, F4b.** How much of the stream length displays active lateral cutting (%): ______

F5. Percent of the total bank length unstable (0-5%; 6–25%; 26–45%; over 45%; NC): __________

F6a. Is the streambank altered by on-site human activities? (Yes; No; NC): ______ *Not collected prior to 1991*

If **Yes, F6b.** Percent (%) of the bank length that has human-caused alterations? ______

F6c. Of this, how much resulted from: (must approx. 100%)

Grazing: ______ Logging: ______ Railroads: ______ Vegetation Removal: ______

Roads: ______ Mining: ______ Recreation: ______ Other: ______

Explain “other”: __________

F7. Percent of the streambanks with deep, binding root mass (0-35%; 36–65%; 66–85%; over 85%; NC): ______

F8. Percent of polygon with sufficient fine material to hold water and act as a rooting medium (0-35%; 36–65%; 66–85%; over 85%; NC): ______ *Not collected prior to 1991*

F9. Rosgen stream types recorded and the percent (%) of the stream length accounted for by each:

Rosgen 1: ____ / ______ Rosgen 2: ____ / ______ Rosgen 3: ____ / ______ Rosgen 4: ____ / ______

F10a. Does the 7.5 min. topo map accurately represent the sinuosity of the stream? (Yes; No; NA; NC): ______

If **No, F10b.** Determine sinuosity in the field; If **Yes,** determine sinuosity in the office from topo map: ________

F11. Average non-vegetated stream channel width: (ft) ________ ; (m): _______ *Not collected prior to 1989*

F12. Stream gradient (percent): _______

F13a. Active downcutting of the stream? (Yes; No; NC):_______ If **Yes, F13b.** Percent (%) of stream actively downcutting:_______

F14a. Headcuts present? (Yes; No; NC):______ If **Yes, F14b.** No. of headcuts: _____ **F14c.** Average headcut height (ft):_____

F14d. Location of headcut(s): ______________________________

F15a. Is the stream channel braided (has multiple active channels during normal flows)? (Yes; No; NC): _______

If **Yes, F15b.** Percent of the stream channel that is braided: _______ *Not collected prior to 1991*

F16. Indicate the best description of channel incisement (A; B; C; D): ______ *Not collected prior to 1990*

F17a. Is there exposed soil surface (bare ground)? (Yes; No; NC): ______ If **No** or **NC,** go to item **F19.**

F17b. Percent (%) of the polygon which is exposed soil surface (bare ground): _________

F17c. Of this, how much is due to Natural Processes: _______ Human-caused disturbance: ______ (must approx. 100%)

F17d. Within ***each*** category (natural & human-caused), how much resulted from the listed processes?

NATURAL PROCESSES *(must approx. 100%)*		**HUMAN-CAUSED PROCESSES** *(must approx. 100%)*	
_______ Erosional	_______ Type Dependent	_______ Grazing	_______ Construction
_______ Depositional	_______ Saline/Alkaline	_______ Logging	_______ Mine tailings
_______ Wildlife Use	_______ Within Veg. Channel Bottoms	_______ Recreation	_______ Other

_______ Other Explain “Other”: ______________________________

F18. Non-vegetated ground cover. **(Note:** Bare ground and vascular plant cover recorded above.)

Rocks (>2.5 in.): _______ Moss: _______ Litter and Duff: _______ Wood: _______

F19. Are channel point bars revegetating? (Yes; No; NA; NC): _______

F20a. Are side drainages and hillslopes contributing to degradation of the system? (Yes; No; NA; NC): _______

If **Yes, F20b.** Human-caused? (Yes; No; NA; NC): _______ Causes: ______________________________

F20c. Natural cause? (Yes; No; NA; NC): ______ Major soil parent material: ______________________________

F21. Is there a nearby source ***on the system*** for large woody debris to enter the stream? (Yes; No; NA; NC):_______

F22a. Average riparian zone width (ft): ________ ; (m): _______

F22b. Riparian zone width range (ft): _______ to _______ ; (m): _______ to _______

F23. Is the average riparian zone widening? (Yes; No; NA; NC): ________

F24. Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting? (Yes; No; NA; NC): _______

F25a. Animal-caused pugging and/or hummocks present? (Yes; No; NC): _______ *Not collected prior to 1991*

If **Yes, F25b.** Percent (%) of polygon affected: ________

F25c. Distribution of hummocks/pugging: Within streambanks: _______ Remainder of polygon:_______ (must approx. 100%)

F26a. Are seeps or springs present? (Yes; No; NC): _______ *Not collected prior to 1993*

If **Yes, F26b.** Number of seeps and springs: _______

F26c. How many springs and seeps had hummocks and/or pugging in 25% or more of the wetted area? _________

F26d. Location of the springs and seeps: ______________________________

F27a. Is wetland type a pooled channel of an intermittent stream (item C1)? (Yes; No; NC): ______ *Not collected prior to 1991*

If **Yes, F27b.** Percent of the channel length with pooled water: _________

F27c. Is this pooled water expected to remain at the surface through the remainder of the growing season? (Yes; No): ______

F27d. Location of the pools: ______________________________

Record ID No: ____________

F28a. Is there evidence of beaver in the polygon? (Yes; No; NC) ______ *Not collected prior to 1992 and most of 1993*

If **Yes, F28b.** (Active; Inactive): ________ **F28c.** Describe the type and amounts of beaver activity observed:

F28d. Number of beaver dams and lodges observed: ______

F28e. Level of beaver activity (number of stems chewed) (1-25; 26-100; over 100; NC): ________

F28f. How many beavers were observed? ______

Where? ____________________

F29. Comments (Summarize unique characteristics or problems not evident from the data collected. Include topics related to any of the optional data. Consider current and historic attributes resulting from human-caused and natural processes.):

F30. Detailed description of upper and lower ends of the polygon:

PHOTOGRAPH DATA

Record ID No: ______________

G1a. Identification of photos (taken at the ***upstream*** end of polygon): Roll # __________ Photographer: ______________

Photo numbers: (upstream): __________ (downstream): __________ (others): ______________

G1b. Location of "other" photos: ______________________________

G1c. Description of views (up): ______________________________

(down): ______________________________

(others): ______________________________

G2a. Is there an adjacent polygon upstream of this polygon? (Yes; No): ______

G2b. Is there an adjacent polygon downstream of this polygon? (Yes; No): ______

G3a. Identification of photos (taken at ***downstream*** end of polygon): Roll # __________ Photographer: ______________

Photo numbers: (upstream): __________ (downstream): __________ (others): ______________

G3b. Location of "other" photos: ______________________________

G3c. Description of views (up): ______________________________

(down): ______________________________

(others): ______________________________

G4. Film and Camera Specifications

Film brand: ______________ Film speed (ASA): ______ Lens diameter (mm): ______ Lens focal length (mm): ________

OPTIONAL DATA

H1. Aspect: ________

H2. Vegetative use by animals (0-25%; 26-50%; 51-75%; 76-100%): ______________________

H3. Adjacent uplands (Agriculture; Grassland; Shrubland; Forest; or Other): ______________ ______________

H4a. Were Category 2 (T & E) plant species observed? (Yes; No): ______ If **Yes, H4b.** Species: ________ ________ ________

H4c. Location(s): ______________________________

H5a. Do subsurface water supplies, independent of flowing surface water in the area, appear to influence area vegetation? (An example of this is a hardwood draw with riparian vegetation, but rarely flowing surface water.) (Yes; No): ______

If **Yes, H5b.** Describe the situation:

____

H6 Bankfull width/depth ratio: ______

H7. Entrenchment ratio (floodprone width/bankfull width) (<1.4; 1.4-2.2; >2.2): ______________

H8. Distribution of exposed soil surface (item F17b) (must approx. 100%):

Inside/outside the bank/channel area: Inside: ______ Outside: ______

H9. Percent of streambank accessible to livestock: ______

Record ID No: ________

H10a. Has the bank configuration or channel profile been modified by construction? (Yes; No; NC): ______

If **Yes, H10b.** How much of the bank or channel length is modified (%)? ______

H10c. What part resulted from the various sources: (must approx. 100%)

Dikes	______	Road Construction	______	Railroads	______
Berms	______	Water Diversion Structures	______	Mining	______
Dams	______	Vegetation Removal	______	Bridges	______
Rip-rap	______	Channelization	______	Logging	______
Other	______	Explain "Other": ______			

H10d. Location(s): ______

H10e. If human-caused channel modifications are present, are they stable? (Stable; Unstable): ______

H10f. What is the effect of the modifications on the immediate and downstream channel?

______

Waterfowl Data

H11a. Were waterfowl nests or broods observed? (Yes; No): ______

If **Yes, H11b.** Describe: ______

Fishery Data

H12a. Does the polygon contain a fishery? (Yes; No; Unknown): ______

If **Yes, H12b.** Is it a sport fishery, non-sport fishery, or unknown: ______

H12c. Fish types present, if known (use common names or descriptions): ______

H12d. How many fish were observed? (0; 1-10; 11-50; >50): ______

H12e. If the polygon does not contain a fishery, is there potential for one? (Yes; No; Unknown): ______

Explain: ______

Amphibian and Reptile Data

H13a. Were amphibians observed? (Yes; No): ______

If **Yes, H13b.** Number observed: Frogs: ______ Toads: ______ Salamanders: ______

H14a. Were reptiles observed? (Yes; No): ______

If **Yes, H14b.** Number observed: Snakes: ______ Turtles: ______ Lizards: ______

H15. List amphibian or reptile species and the quantity of each identified in the polygon.

Spp. #1 ______ No.: ______ Loc.: ______

Spp. #2 ______ No.: ______ Loc.: ______

Spp. #3 ______ No.: ______ Loc.: ______

Spp. #4 ______ No.: ______ Loc.: ______

Threatened and Endangered Species Data

H16a. Were T & E animal species observed? (Yes; No): ______

If **Yes, H16b.** What species? Peregrine Falcon: ______ Bald Eagle: ______ Bull Trout: ______

Peregrine Falcon Nest: ______ Bald Eagle Nest: ______

H16c. Other species observed?

Species	Number
______	______
______	______
______	______
______	______

H16d. Location in polygon where T & E animals or nests were sighted:

______