FINAL REPORT

AVIAN-HABITAT RELATIONSHIPS: A LITERATURE REVIEW AND ASSESSMENT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

The main goal of this review and assessment is to identify how bird survey data collected along the Yellowstone River can best be used to inform future Yellowstone River Conservation District Council Cumulative Effects analyses. These analyses focus on describing the potential impacts of land use management along the Yellowstone River on avian communities. To understand how land use potentially impacts birds, it is necessary to understand how changes to habitat resources caused by land use could influence characteristics of bird communities. The specific objectives of this study were to conduct a literature review to identify relationships between riparian birds and habitat resources, summarize these relationships in the context of the potential impacts of land use management on bird communities along the Yellowstone River, and outline protocols for future Cumulative Effects analyses.

Six main impacts of land use along the Yellowstone River are identified:

1) Fragmentation and loss of forest habitat
2) Loss of structurally complex cottonwood forest habitat
3) Expansion of detrimental species: Brown-headed Cowbirds
4) Expansion of detrimental species: Invasive competitors
5) Spread of invasive plant species
6) Direct adult or nest mortality

The first three impacts receive the most discussion and are the focus of this report. For each of these impacts, land use practices driving changes to habitat resources are identified and avian responses to habitat change are reviewed. Relevance of results to Yellowstone River bird communities are discussed, as well as two types of potential future analyses, including analyses that use local-scale data to validate identified avian-habitat relationships, and reach-scale analyses that quantify characteristics of land use and habitat resources that are proposed to impact bird communities.

These analyses will allow for inference about how changes in land use and habitat resources may impact bird communities when assessing Cumulative Effects. Understanding avian-habitat relationships along the Yellowstone River in the context of Cumulative Effects will help to identify relevant aspects of habitat that are both important to birds and impacted by land use. Furthermore, using available data to quantify changes in land use or habitat along the Yellowstone River will allow for an assessment of the magnitude of potential Cumulative Effects that may impact bird communities.

INTRODUCTION AND OBJECTIVES

The purpose of this review and assessment is to identify how bird survey data collected along the Yellowstone River can best be used to inform future Yellowstone River Conservation District Council (YRCDC) Cumulative Effects analyses. In 2006 and 2007, bird surveys were conducted for the YRCDC Avian Study quantifying the distribution of riparian bird species along the Yellowstone River. Additional riparian bird surveys conducted by Montana Audubon along the Yellowstone in 2012 produced more data about bird communities along the river.

Cumulative Effects analyses will focus on describing the potential impacts of land use management along the Yellowstone River on riparian bird communities. For terrestrial animals such as riparian birds, land use management along rivers usually impacts species indirectly through changes to habitat resources. Consequently, to understand how land use along the Yellowstone River potentially impacts birds, it is necessary to understand how changes to habitat resources caused by land use could influence characteristics of bird communities. The main goal of this study is to identify relationships between riparian birds and habitat resources that are relevant to Yellowstone River Cumulative Effects. The specific objectives were to:

1) Conduct a literature review to identify relationships between riparian birds and habitat resources that are relevant to the Yellowstone River system.
2) Summarize these identified relationships between riparian birds and habitat resources in the context of the potential impacts of land use management on bird communities along the Yellowstone River.
3) Outline protocols for future Cumulative Effects analyses using existing avian data and other environmental data sets compiled for the Yellowstone River.

Understanding avian-habitat relationships along the Yellowstone River in the context of Cumulative Effects will help to identify relevant aspects of habitat that are both important to birds and impacted by land use. This knowledge will guide efforts to use available data for quantifying changes in land use or habitat along the Yellowstone River, and will allow for an assessment of the magnitude of potential Cumulative Effects that may impact bird communities.

METHODS

To identify important relationships that exist between riparian bird communities and habitat resources, I reviewed published research papers, as well as reports and other gray literature from government, academia, and private organizations. I focused on studies that occurred in deciduous riparian habitats in North America, with special attention given to studies in the West.

The assessed relationships represent the impacts of land use drivers on avian habitat resources, and the expected avian responses to changes in that habitat resource:

Land use driver → Avian habitat resource → Avian response

Avian habitat resources are specific aspects of habitat that influence the distribution and abundance of species or the success of avian populations. Impacts to habitat resources are generally reflected in two ways, either through changes to the availability of suitable habitat, or through changes to the quality of habitat that is available. Habitat availability is altered through changes in the extent, composition, and configuration of habitat that provides necessary resources to avian communities. Habitat quality is altered when existing habitat is degraded through changes to biological interactions, such as changes to populations of nest parasites or competitors, or changes in the amount or intensity of interactions with humans that result in direct mortality of individuals. The avian response is the aspect of the avian community that is expected to change as a result of impacts to habitat resources, for example the number of species present or the abundance of a particular species.

The results from this review are organized by 'Physical Impacts', which are the general impacts to habitat resulting from land use activities. Once avian-habitat relationships are identified for each Physical Impact, metrics and existing datasets are identified (when possible) for quantifying each of the parts of the relationship. These metrics could then be used in future analyses of Cumulative Effects along the Yellowstone River. Two types of potential future analyses are discussed:

1) Analyses that use local-scale data describing avian communities and habitat along the Yellowstone River to validate the relationships identified in this review and provide additional evidence that they are relevant to the Yellowstone River system.
2) Reach-scale analyses that quantify characteristics of land use and habitat resources that are proposed to impact bird communities based on relevant avian-habitat relationships from this review. These analyses will help to infer how changes in land use and habitat resources may impact bird communities when assessing Cumulative Effects.

Both of these analyses would use the avian and environmental datasets currently incorporated into the Cumulative Effects Database. Data were collected in 2006 and 2007 for the YRCDC Avian Study at over 300 study sites in 21 reaches from Big Timber to Sidney, Montana. This dataset quantifies, for each study site, the presence and abundances of 64 bird species (see Appendix 1 for a list of all of the species and their scientific names). Additionally, data from the 2012 Montana Audubon field study were collected at over 340 sites from Billings to Sidney using similar methodology as the Avian Study. One additional dataset exists that could potentially be incorporated into the Cumulative Effects Database; in 2002, birds were surveyed for the Upper Yellowstone River Task Force at 130 sites along the river from Gardiner to Livingston (Hansen et al. 2003). All of these datasets can be used to calculate metrics that represent avian responses, which could then be incorporated into the Cumulative Effects Database and used for future data summaries and analyses.

Characteristics of land use and riparian habitat, and changes in these landscape features over time, have been quantified in various datasets for the Yellowstone River. These datasets include efforts that describe riparian vegetation (DTM Consulting, Inc. 2008) and land use (DTM Consulting, Inc. 2013) within the Yellowstone River corridor, as well as various geomorphic characteristics of the floodplain (DTM Consulting, Inc. and Applied Geomorphology, Inc. 2007). With these data, it is possible to summarize and quantify how land use may be impacting bird habitat resources, and consequently infer how bird communities may in turn be affected.

Based on their expert knowledge of the Yellowstone River system, the YRCDC Cumulative Effects

Working Group identified six main Physical Impacts representing changes to habitat resources caused by various land uses along the Yellowstone River:

1) Fragmentation and loss of forest habitat
2) Loss of structurally complex cottonwood forest habitat
3) Expansion of detrimental species: Brown-headed Cowbirds
4) Expansion of detrimental species: Invasive competitors
5) Spread of invasive plant species
6) Direct adult or nest mortality

These Physical Impacts are the focus of this assessment and report. The first three impacts receive most of the attention because data exist to substantiate important relationships that may exist along the Yellowstone River. For the last three impacts, discussion is limited to a brief summary of results from the literature review.

GENERAL RESULTS

I reviewed over 200 papers for this assessment. Information was generally abundant, although studies from the West were sometimes scarce. The three main Physical Impacts targeted for this review are very relevant to avian conservation and management in general, as many of them are often cited as main factors in the population declines of many North American bird species. Specific variables used to measure habitat condition varied across studies, and often depended on the research question, management concern, or region where the study occurred. However, within a given Physical Impact, general habitat metrics that were consistently related to measures of riparian bird communities were evident. These measures of habitat condition are discussed in detail for each of the Physical Impacts in the sections following the '*General Results*'.

Avian Responses

Most studies looked at the same general avian responses, specifically bird species richness, the richness of particular guilds, and the abundances of individual focal species. Bird species richness measures the number of different species observed at a site. Richness is a good indicator of habitat condition because it often reflects the availability of resources in a given habitat; if a broad diversity of nesting and food resources exists at a site, more species would be expected to be there to use those diverse resources.

Guilds are groups of species that use similar resources, and are useful indicators of habitat condition because they allow for an assessment of the availability of certain types of resources in a given habitat. Examining the collective responses of species in a guild may provide strong evidence for how particular changes in habitat are influencing certain types of bird species. The most common types of guilds encountered in riparian habitat studies include guilds based on general habitat preferences (e.g. forest versus edge habitat), and guilds representing nesting and foraging strategies (e.g. canopy nester or ground forager).

Many studies also examined the responses of groups of species based on a shared conservation or management status. Analyses using these types of species groups allow for an assessment of the impacts of habitat changes on groups of species of concern. For example, riparian obligates, a group of specialist species largely dependent on riparian habitats, were often included in analyses of avian responses to habitat condition. However, results from analyses using conservation-based groups may be ambiguous or difficult to interpret because group association does not reflect habitat use, and species do not necessarily respond to habitat changes in the same ways (Faaborg 2002, Gentry et al. 2006). A more informative way to assess impacts to species of concern is to discuss the responses of these species as a subset of habitat guilds. For example, of all the species in a certain habitat guild that are predicted to be negatively impacted by a particular habitat change, who of those species have a special conservation status? Including a discussion such as this will aide in the identification of the species most at risk from the effects of particular changes in habitat condition. The types of species that may be especially impacted by changes to habitat resources include state-listed species of concern, federally listed threatened or endangered species, or species with declining population trends. Knowledge about potential impacts to these most vulnerable species is especially useful for assessing the magnitude of the impact and informing management recommendations.

In summary, the key avian responses that demonstrated the strongest relationships with measures of riparian habitat condition included:

1) Species richness
2) Richness of various habitat guilds
3) Abundances of individual species, including:
    - Riparian obligates
    - Declining species
    - Species of general conservation concern

These general avian responses are the focus of the discussion of avian-habitat relationships for each of the Physical Impacts. The types of habitat guilds used varies based on the nature of the Physical Impact, and will be discussed in detail in each section below. As a part of this review, designations of habitat guild associations and conservation status were determined for all of the 64 avian species documented along the Yellowstone River in the YRCDC Avian Study (see Appendix 1). Species were placed into habitat guilds based on published life-history accounts and results from empirical studies. Twelve species were determined to be 'Riparian Obligates' based on an assessment of western riparian species conducted by Rich (2002), or by other life-history accounts. Species were determined to have declining populations based on results from the Breeding Bird Survey, a long-term monitoring program designed to track the status and trends of North American bird species (Sauer et al. 2012). Species were designated 'declining' if long-term (1966-2011) population trends for birds in the Central Region of the US were significantly negative. The Central Region of the US was used because the majority of study reaches along the Yellowstone River fall into this region, so trends should be relevant to Yellowstone River bird populations. Eighteen of the 64 species were designated as 'Declining Species'. Finally, nine species were determined to be species of general conservation concern because they were designated as either a 'Potential Species of Concern' or a 'Species of Concern' by the Montana Natural Heritage Program (MTNHP). Potential Species of Concern are those “native taxa for which current, often limited, information suggests potential vulnerability”, while Species of Concern are those “native taxa that are at-risk due to declining population trends, threats to their habitats, restricted distribution, or other factors" (MTNHP 2013). See Appendix 1 for habitat guild and conservation status designations for each of the Yellowstone River species.

Species of Concern

Special attention is given to the four avian species that are identified as Species of Concern in Montana by MTNHP. Three of these species are also designated as 'Watchlist Species' by Partners in Flight (PIF), an international partnership of private and government organizations that publishes a formal assessment of the conservation status of North American bird species. Watchlist Species are "those which are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges" (Panjabi et al. 2005). Conservation status is also reported for Montana Fish Wildlife and Parks (MTFWP) or Bureau of Land Management (BLM) when appropriate. Following is a general description of habitat and conservation status for each of these species, retrieved from the MTNHP Montana Field Guide (MTNHP 2013).

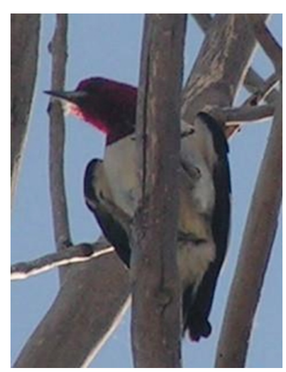
Black-billed Cuckoo

- Habitat: Breeds east of the Rocky Mountains in wooded draws, forest edges, thickets, and shelterbelts. In Montana, they are most often found in riparian cottonwoods, green ash, and American elm forests with a shrubby understory.
- Conservation Status: PIF Watchlist Species, MTNHP Species of Concern, MTFWP Species of Moderate Conservation Need.
- Reason for Conservation Status: Steep long-term population declines recorded throughout North America.

Bobolink

- Habitat: Breeds throughout Montana in tall grass and mixed grass prairies and hayfields.
- Conservation Status: MTNHP Species of Concern, BLM Sensitive species.
- Reason for Conservation Status: Recent large population declines in Montana and surrounding areas.

Red-headed Woodpecker



- Habitat: Breeds throughout the eastern half of Montana in riparian forest along major rivers, or in open savannah with adequate canopy cover and snag density.
- Conservation Status: PIF Watchlist Species, MTNHP Species of Concern, MTFWP Species of Moderate Conservation Need, BLM Sensitive species.
- Reason for Conservation Status: Steep long-term population declines recorded throughout North America.

<u>*Least Tern*</u>

- Habitat: Breeds on unvegetated sand and gravel bars of large rivers and reservoirs, particularly along the Missouri and Yellowstone Rivers.
- Conservation Status: Federally Endangered Species, PIF Watchlist Species, MTNHP Species of Concern, MTFWP Species of Greatest Conservation Need.
- Reason for Conservation Status: Inundation of nest sites and habitat loss has led to population declines throughout the species range; Yellowstone River nesting population is generally less than 30 birds.

Effects of Physical Impacts are specifically discussed for each of these species in the sections below, when appropriate.

<u>PHYSICAL IMPACT: FRAGMENTATION AND LOSS OF FOREST HABITAT</u>
The amount and configuration of forest cover are important habitat characteristics influencing the abundance and distribution of birds. Habitat loss and fragmentation are main factors contributing to the population declines of many bird species.

<u>Land Use Drivers</u>
Land use practices can significantly alter the extent and configuration of forest habitat. Along the Yellowstone River, there are three main land use practices that were identified as potential drivers of forest habitat loss and fragmentation, including:

1) **Bank armoring**: The construction of armor along the banks of the river for the protection of transportation, agricultural, and urban land uses restricts natural channel migration and decreases riparian turnover and the creation of new forest habitat.
2) **Riparian conversion - Agriculture**: The conversion of riparian forest to agricultural land uses, such as crop or pasture, leads to a decline in the amount of forest in the riparian zone.
3) **Riparian management - Livestock grazing**: Browsing of cottonwood seedlings and saplings by livestock results in a decline in the regeneration of riparian forest and a loss in recruitment of forest habitat.

All of these land uses result in either a direct or long-term decline in the amount and contiguity of riparian forest habitat available to birds along the Yellowstone River.

<u>Impacted Habitat Resource: Amount and Configuration of Forest Cover</u>
In general, the amount of forest cover in the landscape has a strong effect on characteristics of riparian bird communities. Most riparian studies find measures of forest cover to be important predictors of species occurrence and community attributes. The amount of forest cover in riparian zones has been quantified in three main ways:

1) **Total forest area**: Total amount of forested habitat in the surrounding landscape, usually measured within one to five kilometers of the river.

2) **Forest width**: Average width of the riparian forest bordering the river.
3) **Patch size**: Total area of each distinct forest patch in the riparian zone.

See Appendix 2 for a detailed list of citations for each of these metrics.

Most of the studies that measured forest width occurred in the eastern part of North America, where deciduous riparian buffer strips are retained in a landscape that was historically contiguous deciduous forest. Western riparian landscapes are different from eastern landscapes in that stringers of deciduous riparian vegetation bordering rivers are naturally distinct from surrounding uplands, and are not generally uniform in width or length. Consequently, relationships between bird communities and riparian width may not be the same in the West as they are in the East. However, studies in the West have found riparian width to be an important predictor of bird distribution (Fletcher and Hutto 2008, Cooke and Zack 2008, 2009). Given the extreme variation in floodplain width that occurs between different reaches along the Yellowstone River, it may be appropriate to consider the potential value of measuring riparian width as an indicator of the amount and configuration of riparian forest habitat available to birds.

In addition to habitat loss, habitat fragmentation is often assumed to negatively affect bird populations. Fragmentation describes changes in the pattern of habitat and how it is distributed across the landscape. Specifically, bird populations may be impacted when the loss of forest habitat results in the division of larger forest patches and an increase in the amount of edge habitat in the landscape. Many studies have documented lower reproductive success for birds nesting in edge habitat due to increased nest predation and parasitism at forest edges (Paton 1994, Donovan et al. 1995). However, most of these studies occurred in the East, where forests were historically extensive and contiguous in nature, and fragmentation has resulted in a dramatically different forest landscape. In the West, riparian habitat is naturally fragmented and, compared with eastern forests, most of the forest habitat is (and has always been) in close proximity to an edge (Heltzel and Earnst 2006, Gentry et al. 2006, Dobkin and Wilcox 1986, Howell et al. 2007, Gergel et al. 2002, Tewksbury et al. 1998). Negative effects of fragmentation on reproductive success have rarely been documented in western studies (Cavitt and Martin 2002, Fletcher 2009, Gentry et al. 2006, Davidson and Knight 2001, Howell et al. 2007, Heltzel and Earnst 2006, Tewksbury et al. 1998, 2006, Morgan et al. 2007; but see Sharp and Kus 2006). Consequently, it may not be relevant to consider the relationships between bird community characteristics and measures of fragmentation (e.g. the amount of edge in the landscape) along western rivers such as the Yellowstone (Gergel et al. 2002).

<u>Avian Responses to Forest Cover</u>

Avian responses to measures of forest cover reflect aspects of community diversity, as well as the diversity and abundance of guilds based on general habitat preferences of species. The guild that responds most consistently to measures of forest cover is the habitat-based 'forest specialist' guild, which includes species that prefer habitats comprised of more extensive forest. Species in this guild are sensitive to the amount of forest cover in the landscape, and collectively and individually are often good indicators of the impacts of forest habitat loss. Key avian responses to measures of forest cover included:

1) **Total species richness:** Increases with forest cover.
2) **Richness of forest specialist species:** Increases with forest cover.
3) **Abundances of individual forest specialist species:** Increase with forest cover.

See Appendix 2 for a detailed list of citations documenting relationships between habitat metrics and these avian responses.

In the West, riparian zones support some of the most extensive deciduous forests available in the landscape, especially compared to drier grassland, shrub, and coniferous upland vegetation communities. Consequently, floodplain vegetation along rivers such as the Yellowstone may be especially important for sustaining regional populations of avian species that depend on large tracts of deciduous forest. Measures that characterize the amount and configuration of forest cover may be good indicators of habitat availability for these species.

It is generally assumed that the abundance of Brown-headed Cowbirds, a nest parasite that has been implicated in the population declines of many avian species throughout North America, increases in areas where forest cover has been reduced and fragmentation has increased. Most studies documenting negative relationships between cowbird abundance and forest cover are located in the East (Donovan et al. 2000), where fragmentation has created open areas and edge habitat in historically extensive forests. Cowbirds depend upon open areas and edges for feeding, so the loss of forest cover has allowed cowbirds to expand their range into formerly inaccessible eastern forests. However, for the naturally fragmented deciduous forests of the West, much of the riparian forest habitat has historically been in close proximity to edges. In these naturally fragmented areas, edge effects related to cowbird parasitism are not expected to be observed (Howell et al. 2007). Consequently, there may not be a strong relationship between cowbirds and measures of forest cover or edge in western riparian systems (Tewksbury et al. 1998, 2006, Goguen and Mathews 2000, Sharp and Kus 2006, Brodhead et al. 2007, Hochachka et al. 1999; but see Stumpf et al. 2012), and cowbirds may not be a relevant avian response to consider for this Physical Impact. Cowbirds are strongly associated with other land use drivers and Physical Impacts that are discussed in later sections of this report.

<u>Summary of Impacts Related to Loss of Forest Habitat</u>
Following is a summary of the key findings and relationships related to the impacts of riparian forest habitat loss:

1) The conversion of riparian habitat to agricultural land uses, the construction of bank armor, and livestock grazing all result in either a direct or long-term decline in the amount and contiguity of riparian forest habitat available to birds along the Yellowstone River.
2) In general, the amount of forest cover in the landscape has a strong effect on characteristics of riparian bird communities and is usually measured as the total area of forest cover in the landscape, the width of the riparian forest, or the size and area of forest patches.
3) Total species richness, species richness of the 'forest specialist' guild (representing species that prefer habitats comprised of extensive forest), and abundances of individual 'forest specialist' species all exhibit strong and consistent positive relationships with measures of forest cover.

Relevance of Results to the Yellowstone River

Of the 27 studies that provided information about relationships between avian communities and measures of forest cover, 15 were located in the West. Eight of those studies occurred within cottonwood forest, similar in species composition and structure to forests along the Yellowstone River. Research studies along the Bitterroot River in Montana (Tewksbury et al. 1998, 2002), Snake River in Idaho (Saab 1999, Tewksbury et al. 2002, 2006), and Missouri River in Montana (Tewksbury et al. 2002) and South Dakota (Gentry et al. 2006) were particularly relevant to the bird species and habitat conditions found along the Yellowstone River.

Results from the YRCDC Avian Study (Jones and Hansen 2009) provide further evidence for the relationships between bird community characteristics and habitat resources documented during the literature review. The percent forest cover at a site was an important factor influencing the distribution of avian species along the Yellowstone; six of 14 species were significantly more abundant with increasing forest cover, while four species were less abundant with increasing forest cover.

Based on results from empirical studies reviewed for the literature assessment and general life-history characteristics, 18 of the species documented along the Yellowstone River during the Avian Study generally exhibit positive relationships with measures of forest cover and are considered to be 'forest specialist' species (Table 1). These species would potentially be most negatively impacted by the loss of cottonwood forest habitat along the Yellowstone River. Of these 18 forest specialist species, eight may be especially vulnerable to the loss of forest habitat due to either declining population trends, their status as a species of management concern, or their relatively exclusive use of riparian forest habitat (Table 1). American Redstarts and Ovenbirds may be especially at risk because they are both experiencing declining populations and are riparian obligate species. Of special consideration is the Black-billed Cuckoo, a Montana Species of Concern that is experiencing steep population declines and is dependent upon riparian forest for breeding habitat. Cuckoo's are sometimes referred to as an 'edge' species because of their preference for shrubby thickets. However, this species may be impacted by fragmentation, as abundance is positively correlated with patch size, and Cuckoo's are often absent from smaller forest fragments (Hughes 2001, Martin 1981, Galli et al. 1976).

Table 1. Yellowstone River bird species identified as 'forest specialist' species based on life-history characteristics and empirical studies, and conservation status for each species.

Species	Sources for a Positive Relationship with Measures of Forest Cover	Declining Trend	Species of General Conservation Concern*	Riparian Obligate
American Redstart	Gentry et al. 2006 (Big Sioux and Missouri Rivers, SD) Kilgo et al. 1998 Peak and Thompson 2006 Sallabanks et al. 2000 Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Bitterroot River, MT)	X		X
Black-billed Cuckoo	Hughes 2001	X	SOC	X
Black-capped Chickadee	Davidson and Knight 2001 (Yampa River, CO) Perkins et al. 2003 Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Snake River, ID)	X		
Black-headed Grosbeak	Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 Tewksbury et al. 2002 Tewksbury et al. 2002 (Snake River, ID)			
Black-and- white Warbler	Conner et al. 2004 Kilgo et al. 1998		PSOC	X
Cedar Waxwing	Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Snake River, ID)			
Downy Woodpecker	Conner et al. 2004 Kilgo et al. 1998			
Gray Catbird	Gentry et al. 2006 (Big Sioux and Missouri Rivers, SD) Saab 1999 (Snake River, ID) Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Snake River, ID)			X
Hairy Woodpecker	Jackson et al. 2002			
House Wren	Davidson and Knight 2001 (Yampa River, CO) Saab 1999 (Snake River, ID) Jones and Hansen 2009 (Yellowstone River, MT)			

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Table 1 continued.

Species	Sources for a Positive Relationship with Measures of Forest Cover	Declining Trend	Species of General Conservation Concern*	Riparian Obligate
Least Flycatcher	Fletcher 2009 (Missouri River, MT) Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Jones and Hansen 2009 (Yellowstone River, MT)			
Ovenbird	Peak and Thompson 2006 Jones and Hansen 2009 (Yellowstone River, MT)	X	PSOC	X
Plumbeous Vireo	Goguen and Curson 2012		PSOC	
Red-eyed Vireo	Conner et al. 2004 Gentry et al. 2006 (Big Sioux and Missouri Rivers, SD) Groom and Grubb 2002 Hodges and Krementz 1996 Keller et al. 1993 Peak and Thompson 2006 Rodewald and Bakermans 2006 Sallabanks et al. 2000 Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT)	X		
Rose- breasted Grosbeak	Wyatt and Francis 2002			
White-breasted Nuthatch	Gentry et al. 2006 (Big Sioux and Missouri Rivers, SD) Tewksbury et al. 2002 (Missouri River, MT)			
Western Wood-pewee	Davidson and Knight 2001 (Yampa River, CO) Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Oregon, Nevada) Jones and Hansen 2009 (Yellowstone River, MT)			
Yellow Warbler	Cooke and Zack 2009 Davidson and Knight 2001 (Yampa River, CO) Gentry et al. 2006 (Big Sioux and Missouri Rivers, SD) Tewksbury et al. 2002 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT) Tewksbury et al. 2002 (Snake River, ID) Jones and Hansen 2009 (Yellowstone River, MT)			X

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

<u>Potential Future Analyses of Avian-Habitat Relationships</u>

Future analyses using avian and habitat data collected along the Yellowstone River may help to validate the relationships identified in the literature review. A one-kilometer landscape scale is suggested for the analyses of avian-habitat relationships; this is the most common and responsive scale used in riparian studies in the West (Tewksbury et al. 2002, Saab 1999). Suggested analyses include the examination of relationships between each of the avian responses and habitat resources that are relevant to this Physical Impact. See Table 2 for a description of the specific metrics and data available for the examination of Yellowstone River avian-habitat relationships. See Section '*Relevance Of Results To Cumulative Effects Analysis*' for a discussion of potential Cumulative Effects assessments.

Table 2. Specific metrics and data available for the examination of Yellowstone River avian-habitat relationships related to the fragmentation and loss of forest habitats.

Metric Type	Metric	Description of Metric (Data Source)
Avian Response	Total species richness	Average number of species observed (Avian Data)
Avian Response	Species richness of forest specialist guild	Average number of forest specialist species observed (Table 1; Avian Data)
Avian Response	Abundances of vulnerable forest specialist species	Average abundances for each of the eight forest specialist species that are either experiencing declining population trends, are species of general conservation concern, or are obligate riparian breeders (Table 1; Avian Data)
Habitat Resource	Total forest area	Area of open timber and closed timber habitat types surrounding each avian study site (Riparian Mapping)
Habitat Resource	Patch size	Size of open or closed timber forest patch surrounding each avian study site and average size of all patches in the surrounding landscape (Riparian Mapping)
Habitat Resource	Forest width	Average width of riparian forest (open and closed timber) surrounding each avian study site (Riparian Mapping)

PHYSICAL IMPACT: LOSS OF STRUCTURALLY COMPLEX FOREST HABITAT

Structurally complex forests are characterized by multiple vertical layers of vegetation that provide well-developed, dense understory, midstory, and canopy strata. Structurally complex habitats generally harbor more species than forests with simple structure because there are more niches providing different types of nesting and foraging resources (MacArthur and MacArthur 1961). A decline in the extent of structurally complex forest in the landscape often results in a loss of species that depend upon habitats with dense and diverse vegetation, and an overall loss of species diversity.

In general, the structural complexity and diversity of vegetation within a habitat is one of the most important factors influencing the distribution of bird species (MacArthur and MacArthur 1961, James 1971, Cody 1981). In the semi-arid West, riparian zones usually contain the most structurally complex forest in the landscape, and provide important resources for avian species dependent upon complex riparian habitats. Declines in the amount of structurally complex forest available to birds in the riparian zone could result in the loss of certain riparian species and an overall decline in riparian bird diversity.

Land Use Drivers

Land use practices can significantly alter the local habitat characteristics of riparian vegetation. Along the Yellowstone River, there are two main land use practices that were identified as potential drivers of change in the availability of structurally complex forest habitat, including:

1) **Bank armoring**: The construction of armor along the banks of the river for the protection of transportation, agricultural, and urban land uses restricts natural channel migration and decreases rates of riparian turnover. The resulting decline in the regeneration of cottonwood forest leads to a loss of structurally complex early and mid-successional cottonwood forest habitat types, and an increase in the proportion of decadent, structurally simple forest.
2) **Riparian management - Livestock grazing**: Heavy grazing in cottonwood forest leads to a decline in the density of understory and midstory vegetation, and results in more structurally simple forest habitat.

These land uses result in either an immediate or long-term decline in the extent and proportion of structurally complex riparian forest habitat available to birds along the Yellowstone River.

<u>Impacted Habitat Resource: Amount of Structurally Complex Forest Habitat</u>
Habitat complexity is usually quantified at a local scale, by measuring the density of distinct vertical vegetation strata within the forest. However, it is difficult to quantify local-scale habitat characteristics, such as vegetation complexity, at a landscape scale; only one riparian study attempted to do this. Seavy et al. (2009) quantified characteristics of the forest canopy within the landscape (i.e. 50 hectares surrounding bird sampling areas) using LiDAR and found that many riparian species responded to this measure of vegetation structure, suggesting that forest canopy cover may be a good landscape-scale indicator of habitat structure that is important to riparian birds. Studies have described a positive relationship between the amount of forest canopy cover and the structural complexity of cottonwood forests in Montana (Boggs and Weaver 1994, Hansen et al. 1995) and elsewhere (Merritt and Bateman 2012). Based on these relationships, landscape-scale metrics can potentially be derived using forest canopy cover as a surrogate for understory vegetation structure.

Vegetation structure and complexity in riparian habitats can be quantified in three ways:

Local scale:
1) **Cover at various vertical strata**: Vegetation volume or density at various heights, usually using ground, shrub, low canopy, and high canopy strata categories.
2) **Habitat types with different structural characteristics**: Classification of sites into different habitat categories based on structural characteristics of the forest stand.

Landscape scale:
3) **Area of forest with different canopy cover characteristics**: Forest patches with higher canopy cover represent stands with greater structural complexity.

Many studies examined relationships between characteristics of vegetation complexity and bird community attributes using these habitat measures, and most found complexity to be a good predictor of bird distribution. See Appendix 3 for a detailed list of citations for each of these metrics.

Avian Responses to Habitat Complexity

Avian responses to measures of habitat complexity reflect aspects of community diversity, as well as the diversity and abundance of guilds based on where species forage or nest within the forest. The guild that responds most consistently to measures of habitat complexity is the 'forest understory' guild, comprised of species that forage or nest in the shrub strata of the forest. Species in this guild are sensitive to the availability of complex forest habitat within the landscape because they depend upon well-developed vegetation in the forest understory. Consequently, these species are likely to be good indicators of impacts related to declines in the amount of structurally complex habitats in riparian zones. Species belonging to other guilds, such as those that nest in cavities, generally have weaker relationships with habitat complexity than those species that forage or nest in understory vegetation (Gutzwiller and Anderson 1987, Scott et al. 2003). Key avian responses to measures of habitat complexity included:

1) **Total species richness:** Increases with structural complexity.
2) **Richness of forest understory species:** Increases with structural complexity.
3) **Abundances of individual forest understory species:** Increase with structural complexity.

See Appendix 3 for a detailed list of citations documenting relationships between habitat metrics and these avian responses.

Unlike many other land use drivers that have long term or large scale impacts on habitat that are difficult to measure and must be inferred (e.g. bank stabilization), grazing directly changes the structure of riparian habitat on a local scale that is relatively easy to quantify. Given this, and considering that grazing has been identified as a substantial threat to riparian habitats in the West (Kauffman and Krueger 1984), many studies have directly and simultaneously examined how livestock grazing modifies habitat structure, and how these changes in habitat subsequently impact bird communities. Researchers generally examined the impacts of grazing by comparing differences in habitat characteristics and bird communities in a grazed area versus an ungrazed area, or by measuring changes in birds and habitat after grazing has either been initiated or removed from an area. Grazing in riparian forest may cause habitat simplification due to a loss of understory vegetation (Scott et al. 2003, Taylor 1986, Ammon and Stacey 1997, Schulz and Leininger 1990, 1991, Mosconi and Hutto 1982, Wales 2001, Saab 1998, Eggers 2005), and total bird species richness, species richness of understory species, and abundances of some understory species all decline with the loss of structural complexity caused by grazing (see Appendix 3 for citations). Species belonging to other guilds, such as those that forage in the canopy or nest in cavities, are less impacted by grazing than those species that depend on understory vegetation (Bock et al. 1993, Wales 2001, Earnst et al. 2005, 2012, Mosconi and Hutto 1982, Saab 1998, Saab et al. 1995). However, the strength of the relationship between grazing and birds is often dependent upon the intensity and timing of grazing in a given riparian area. Differences in bird and vegetation communities are often not evident in lightly grazed areas versus ungrazed areas, or in areas where grazing occurs only during the fall or winter (Sedgwick and Knopf 1987, Stanley and Knopf 2002, Nelson et al. 2011, Sedgwick and Knopf 1991, Lucas et al. 2004).

Summary of Impacts Related to the Loss of Habitat Complexity

Following is a summary of the key findings and relationships related to the effect of declines in the availability of structurally complex riparian forest habitat:

1) Livestock grazing and the construction of bank armor cause either direct or long-term declines in the amount of structurally complex forest habitat available to birds along the Yellowstone River.
2) The structural complexity of riparian forest has a strong effect on characteristics of riparian bird communities and can be measured either at a local scale by quantifying the vertical density of vegetation in the forest, or at a landscape scale by quantifying the amount of forest with greater structural complexity in the canopy.
3) Total species richness, species richness of the 'understory specialist' guild (representing species that forage or nest in the shrub layer of riparian forest), and abundances of individual 'understory specialist' species all exhibit strong and consistent positive relationships with measures of structural complexity, and negative relationships with heavy grazing.

<u>Relevance of Results to the Yellowstone River</u>
Results from studies in all regions of North America found that habitat structure was a very important driver of bird distribution. However, many studies were especially relevant to the Yellowstone River system because they were located in cottonwood gallery forest along large western rivers in Montana or bordering states. Walcheck (1970), Scott et al. (2003), and Fletcher and Hutto (2008) all examined relationships between birds and habitat complexity along the Missouri River in Montana, while Rumble and Gobeille (2004) investigated birds and habitat along the Missouri in South Dakota. Mosconi and Hutto (1982) measured impacts of grazing and habitat structure on riparian birds along the Bitterroot River in Montana, while Tewksbury et al. (2002) examined the impacts of grazing for birds along the Snake River in Idaho and the Missouri River in Montana. Results from these studies are especially informative because they consider habitats with similar vegetation species composition and structure, and often discuss bird species that also occur along the Yellowstone River.

Results from the YRCDC Avian Study provide further evidence for the relationships between bird community characteristics and habitat complexity (Jones and Hansen 2009). In general, structurally complex cottonwood forest habitats were abundant along the river, and habitat structure was an important factor influencing the distribution of avian species. Total species richness was highest in structurally complex habitats with a dense shrub understory, and guilds comprised of species that nest and forage in the forest understory were most abundant in habitats with dense shrub. Five of 13 species analyzed were significantly more abundant in structurally complex cottonwood forest habitats with a dense shrub understory.

Eleven of the 64 species documented along the Yellowstone River generally exhibited positive relationships with habitat complexity (Table 3). These understory specialist species depend upon structurally complex cottonwood forest habitats because they nest or forage in the understory or lower canopy. Consequently, these species would potentially be most negatively impacted by the loss of structurally complex cottonwood forest habitat caused by grazing and bank stabilization along the Yellowstone River. Studies that investigated the impacts of grazing on understory vegetation and birds provide further evidence for these potential impacts; eleven of the twelve Yellowstone River understory specialist species have been reported to be negatively impacted by grazing (Table 3).

Of these eleven understory specialist species, 7 may be especially vulnerable to the loss of structurally complex habitats due to either declining population trends, their status as a species of general conservation concern, or their relatively exclusive use of riparian forest habitat (Table 3). American Redstarts and Common Yellowthroats may be especially at risk because they are both experiencing declining populations and are riparian obligate species. Of special consideration is the Black-billed Cuckoo, a Montana Species of Concern that is particularly dependent upon structurally complex cottonwood forest for breeding habitat (Hughes 2001).

Table 3. Yellowstone River bird species identified as 'understory specialist' species based on life-history characteristics and empirical studies, and conservation status for each species.

Species	**Sources for a Positive Relationship with Measures of Understory Habitat Complexity and a Negative Relationship with Grazing**	**Declining Trend**	**Species of General Conservation Concern***	**Riparian Obligate**
American Goldfinch	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Walcheck 1970 (Missouri River, MT) McGraw and Middleton 2009 *Grazing*: Bock et al. 1993			
American Redstart	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Sherry and Holmes 1997 *Grazing*: Mosconi and Hutto 1982 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT)	X		X
Black-billed Cuckoo	*Habitat complexity*: Hughes 2001 Rumble and Gobeille 2004 (Missouri River, SD)	X	SOC	X
Black-headed Grosbeak	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Ortega and Hill 2010 *Grazing*: Earnst et al. 2012 Tewksbury et al. 2002 (Missouri River, MT and Snake River, ID)			
Cedar Waxwing	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Witmer et al. 1997 *Grazing*: Bock et al. 1993 Tewksbury et al. 2002 (Snake River, ID)			

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Table 3 continued.

Species	Sources for a Positive Relationship with Measures of Understory Habitat Complexity and a Negative Relationship with Grazing	Declining Trend	Species of General Conservation Concern*	Riparian Obligate
Common Yellowthroat	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Walcheck 1970 (Missouri River, MT) Guzy and Ritchison 1999 *Grazing*: Bock et al. 1993 Krueper et al. 2003 Mosconi and Hutto 1982 (Bitterroot River, MT)	X		X
Gray Catbird	*Habitat complexity*: Jones and Hansen 2009 (Yellowstone River, MT) Walcheck 1970 (Missouri River, MT) Rumble and Gobeille 2004 (Missouri River, SD) Smith et al. 2011 *Grazing*: Tewksbury et al. 2002 (Missouri River, MT and Snake River, ID)			X
Lazuli Bunting	*Habitat complexity*: Scott et al. 2003 (Missouri River, MT) Greene et al. 1996 *Grazing*: Earnst et al. 2012 Mosconi and Hutto 1982 (Bitterroot River, MT) Tewksbury et al. 2002 (Missouri River, MT and Snake River, ID)			
Song Sparrow	*Habitat complexity*: Jones and Hansen 2009 (Yellowstone River, MT) Scott et al. 2003 (Missouri River, MT) Dickson et al. 2009 Arcese et al. 2002 *Grazing*: Krueper et al. 2003 Earnst et al. 2005, 2012 Mosconi and Hutto 1982 (Bitterroot River, MT) Tewksbury et al. 2002 (Snake River, ID)			X
Spotted Towhee	*Habitat complexity*: Walcheck 1970 (Missouri River, MT) Greenlaw 1996 *Grazing*: Earnst et al. 2005, 2012			

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Table 3 continued.

Species	Sources for a Positive Relationship with Measures of Understory Habitat Complexity and a Negative Relationship with Grazing	Declining Trend	Species of General Conservation Concern*	Riparian Obligate
Yellow Warbler	*Habitat complexity*: Jones and Hansen 2009 (Yellowstone River, MT) Scott et al. 2003 (Missouri River, MT) Walcheck 1970 (Missouri River, MT) Rumble and Gobeille 2004 (Missouri River, SD) Lowther et al. 1999 *Grazing*: Krueper et al. 2003 Earnst et al. 2005, 2012 Tewksbury et al. 2002 (Missouri River, MT and Snake River, ID) Taylor and Littlefield 1986			X
Yellow-breasted Chat	*Habitat complexity*: Jones and Hansen 2009 (Yellowstone River, MT) Scott et al. 2003 (Missouri River, MT) Rumble and Gobeille 2004 (Missouri River, SD) Eckerle and Thompson 2001 *Grazing:* Krueper et al. 2003 Tewksbury et al. 2002 (Missouri River, MT)			X

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Potential Future Analyses of Avian-Habitat Relationships

Future analyses using avian and habitat data collected along the Yellowstone River will likely help validate the bird-habitat relationships identified in the literature review. During the YRCDC Avian Study, relationships between habitat complexity and avian abundance were examined for only 4 of the twelve species identified as 'understory specialist' species (Jones and Hansen 2009). Habitat complexity was quantified by assigning each survey site to one of five cottonwood habitat types that varied in the degree of structural complexity. New analyses could be completed to validate the importance of relationships between habitat complexity and avian abundance for the remaining 8 understory specialist bird species occurring along the Yellowstone River (Table 3).

Forest patches with higher canopy cover may represent patches with higher structural complexity in general. The accuracy of this metric can be assessed by comparing local-scale habitat data collected during the YRCDC Avian Study with landscape-scale habitat mapping data from the Riparian Mapping effort. The Riparian Mapping data classifies riparian forest patches into categories with differing canopy cover characteristics, and data exist for the entire Lower Yellowstone corridor. Vegetation data from the Avian Study were collected at over 200 sites that overlap with the Riparian Mapping data.

The importance of this landscape scale measure of habitat structure to birds could be validated by examining the relationships between total bird species richness, richness of the understory specialist guild, and the abundances of understory specialist bird species relative to canopy cover of the forest patch. If total and understory specialist guild richness is higher, and understory species are more abundant in patches with higher canopy cover, this may provide further support for the use of this landscape-scale metric of habitat structure. See Table 4 for a description of the specific metrics and data available for the examination of Yellowstone River avian-habitat relationships. See Section '*Relevance Of Results To Cumulative Effects Analysis'* for a discussion of potential Cumulative Effects assessments.

Table 4. Specific metrics and data available for the examination of Yellowstone River avian-habitat relationships relevant to the loss of structurally complex forest habitat.

Metric Type	Metric	Description of Metric (Data Source)
Avian Response	Total species richness	Average number of species observed (Avian Data)
Avian Response	Species richness of understory specialist guild	Average number of understory specialist species observed (Table 3; Avian Data)
Avian Response	Abundances of understory specialist species	Average abundances for each of the understory specialist species (Table 3; Avian Data)
Habitat Resource	Cottonwood habitat type	Five cottonwood habitat types with various degrees of structural complexity, ranging from cottonwood forest with an open understory to cottonwood forest with a dense, diverse shrub understory (Avian Habitat Data)
Habitat Resource	Forest habitat type by canopy cover	Two forest habitat types: open timber (<20% canopy cover) and closed timber (>20% canopy cover) (Riparian Mapping)

PHYSICAL IMPACT: EXPANSION OF DETRIMENTAL SPECIES - BROWN-HEADED COWBIRDS

Brown-headed Cowbirds are nest parasites that lay their eggs in the nests of over 100 documented 'host' species. The hosts provide all care for the Cowbird young, often resulting in the neglect of natal young and reduced reproductive output for the host species (Brittingham and Temple 1983, Zanette et al. 2007). Cowbirds were originally limited to the short-grass plains of central North America, where they foraged on insects disturbed by the movements of buffalo herds. Their distribution has significantly expanded in the past century; Cowbirds are now primarily associated with agricultural and developed landscapes throughout North America (Lowther 1993). The negative impact of Cowbirds is a major concern in avian conservation and management, and Cowbird expansion has been implicated in the population declines of many songbird species in North America (Robinson et al. 1995).

Land Use Drivers

Relationships between land use and the distribution of Cowbirds have been well-studied. Cowbirds forage on the ground in open areas where livestock or human development are present and food resources are abundant and easy to find (Lowther 1993). The most important drivers of Cowbird distribution are the proximity to and density of feeding sites in the landscape (Chace et al. 2005, Morrison and Hahn 2002). Researchers that followed Cowbirds fitted with radio-tracking devices reported that preferred Cowbird feeding sites include pastures, corrals, and other rural and exurban areas with livestock and agriculture, as well as open areas and lawns of residential areas (Table 5). Conversely, Cowbirds prefer to breed in forest and woodland habitats where host densities are highest (Chace et al. 2005, Morrison and Hahn 2002, Rothstein et al. 1984), and will consequently commute far distances (on average 1 to 4 kilometers, up to 15 km; Chace et al. 2005) daily between morning breeding habitat and afternoon foraging sites.

Table 5. Preferred feeding and breeding habitats for Brown-headed Cowbirds.

Habitat Type	Habitat	Citations
Feeding	Corrals, feedlots, pastures with livestock	Rothstein et al. 1984, Rothstein et al. 1987, Heath et al. 2010, Borgmann and Morris 2010, Goguen and Mathews 2001, Kostecke et al. 2003, Thompson 1994, Morris and Thompson 1998, Verner and Ritter 1983, Goguen and Mathews 1999, Chace et al. 2005, Howell et al. 2007
	Residential, urban areas	Rothstein et al. 1984, Chace et al. 2003, Chace 2004, Thompson 1994
	Cropland	Howell et al. 2007 *Not important feeding habitat*: Goguen and Mathews 2001, Thompson 1994, Chace et al. 2005
Breeding	Forest or woodland	Howell et al. 2007, Thompson 1994, Goguen and Mathews 2001, Verner and Ritter 1983, Rothstein et al. 1984

The expansion of land uses that provide these types of Cowbird feeding habitats along the Yellowstone River will potentially result in increases in Cowbird abundance and parasitism in riparian forests that constitute prime Cowbird breeding habitat. Along the Yellowstone River, there are three main land use practices that are potential drivers of Cowbird expansion into riparian habitats, including:

1) **Riparian management - Livestock grazing**: Presence of grazing livestock results in an increase in Cowbird feeding opportunities in close proximity to the riparian zone, and a subsequent increase in the abundance of Cowbirds in riparian habitats.
2) **Riparian conversion – Urban/Exurban:** Presence of residential areas in close proximity to the riparian zone results in an increase in Cowbird feeding opportunities associated with lawns, corrals, and other open habitats, and a subsequent increase in the abundance of Cowbirds in nearby riparian habitats.
3) **Riparian conversion – Agriculture:** Presence of agricultural lands, including pastures, crops, and open fields, and associated farmsteads, feedlots, and corrals, results in an increase in Cowbird feeding sites in close proximity to the riparian zone.

These types of land uses within the floodplain of the Yellowstone River may result in the degradation of riparian habitats due to negative impacts of Cowbird parasitism on riparian bird communities. Specific landscape scale metrics that significantly influence Cowbird distribution in riparian habitats include the distance to or density of:

- **Livestock areas** (corrals, feedlots, or actively grazed pastures)
- **Residential, urban, or exurban areas** (rural residences)
- **Agricultural lands** (tilled land or pasture)

The presence of livestock areas in the surrounding landscape are consistently and strongly correlated with Cowbird abundance and rates of parasitism in breeding habitats. Areas grazed by livestock generally have higher insect abundances and shorter grass, which provide optimal foraging opportunities for Cowbirds (Morris and Thompson 1998). When livestock areas are closer to forest habitats, Cowbird abundance and parasitism on host nests are higher. Evidence that Cowbirds are actually responding to livestock is strong because these studies usually document and quantify the presence of livestock, and often report that cowbird feeding areas move with moving cattle (Goguen and Mathews 2001, Kostecke et al. 2003, Goguen and Mathews 1999, Purcell and Verner 1999).

Studies examining the influences of residential or agricultural areas on Cowbird distribution documented these land uses by quantifying the location and density of these cover types in the landscape. Residential and urban areas are generally areas of dense human development, while exurban areas consist of more isolated rural homes or farmsteads. Agricultural cover types may represent any tilled land or open areas such as pasture or hayfields, and often include farmsteads and outbuildings associated with agricultural lands. Cowbird abundance and parasitism are reported to be higher in forest habitats situated in landscapes with greater human development and agriculture. However, because these land uses are represented as cover types, it is less evident as to what aspects of the landscape Cowbirds are directly responding. For example, cowbirds may be responding positively to the presence of grazing livestock and preferred short-grass habitats often associated with agricultural areas, while not depending as much on cropland or other tilled lands that are included in that agriculture cover type. See Appendix 4 for a detailed list of citations for each of these land use metrics.

<u>Impacted Habitat Resource: Habitat Quality – Cowbird Parasitism</u>
Different from previously discussed Physical Impacts, the expansion of Brown-headed Cowbirds into riparian habitats affects bird communities by changing the quality of the existing habitat, not the amount or physical attributes of available habitat. Cowbirds degrade existing riparian habitats by negatively impacting the reproductive success of songbird species (Tewksbury et al. 1998, Heath et al. 2010, Goguen and Mathews 2000, Stumpf et al. 2012). The impacts of cowbirds on the quality of riparian habitats are usually quantified by examining measures of Cowbird distribution or parasitism, specifically:

1) **Cowbird presence or abundance**: The presence of Cowbirds in riparian habitats provides evidence that parasitism is likely impacting habitat quality; higher Cowbird abundance may suggest that parasitism is having a greater impact.
2) **Nest parasitism rates**: The frequency of Cowbird parasitism for nests of host species monitored in a particular riparian bird community, measured either for one focal species or all host species combined.

Evidence exists for significant relationships between these metrics of habitat degradation and land use, suggesting that they are good indicators of the impacts of land use on the quality of riparian habitats in the West. See Appendix 4 for a detailed list of citations documenting these relationships.

These metrics of Cowbird distribution and parasitism are usually measured at a local scale, i.e. within a habitat patch or a study site. It may be possible to quantify potential habitat degradation at a landscape scale by identifying habitats that will likely have higher abundance or parasitism of Cowbirds. Cowbirds prefer to breed in forest habitats that are in close proximity to feeding sites (Table 5), and especially prefer riparian forest in the West (Tewksbury et al. 1999, Young and Hutto 1999, Chace 2004, Chace et al. 2005, Lynn et al. 1998). Consequently, the identification of riparian forest habitats that are close to land uses that provide Cowbird feeding sites may provide a metric for habitat degradation at a landscape scale.

<u>Avian Responses to Cowbird Parasitism</u>

The key avian response to habitat degradation caused by Cowbird parasitism is the **decreased reproductive success of host species** (Brittingham and Temple 1983, Robinson et al. 1995). This response is often difficult to quantify because methods for determining reproductive output are expensive and labor intensive. However, a few studies have measured reproductive output for particular host species in riparian areas in the West, and have provided evidence that parasitism can have a substantial negative effect. Compared with unparasitized nests, nests with Cowbirds often experience decreased fecundity due to declines in the number of natal young successfully fledged (Heath et al. 2010, Tewksbury et al. 1998). Furthermore, total nest loss can be greater due to nest abandonment after parasitism occurs, or predation of natal young by Cowbird adults or young (Goguen and Mathews 2000, Stumpf et al. 2012, Tewksbury et al. 1998).

Knowledge of this general avian response (i.e. lower reproductive output) provides understanding of how Cowbird parasitism directly influences bird species. The negative impacts of Cowbird parasitism may ultimately result in population declines for host species, and subsequent changes to characteristics of avian communities in degraded habitats (e.g. species richness). However, the consequences of habitat degradation on the composition of avian communities are difficult to generalize; a species may be present in a degraded habitat even when reproductive success is low (vanHorne 1983), and correlations between Cowbird parasitism and the distribution of host species are often not evident (Peterjohn et al. 2000, Chace et al. 2005). Therefore, quantifying changes in characteristics of avian communities in degraded habitats may not accurately measure the negative impacts of cowbird parasitism on riparian birds.

<u>Summary of Impacts Related to the Expansion of Brown-headed Cowbirds</u>

Following is a summary of the key findings and relationships related to the effect of habitat degradation due to Cowbird parasitism in riparian habitats:

1) Livestock grazing and the expansion of agriculture and residential development in the riparian zone provide feeding sites for Cowbirds, and may result in increased Cowbird abundance in riparian forest habitat (i.e. preferred Cowbird breeding habitat) along the Yellowstone River.

2) Land use metrics correlated with Cowbird presence in riparian areas include the distance to and density of residential, agricultural, and livestock areas in the surrounding landscape.
3) The amount of habitat degradation caused by Cowbird parasitism is measured by the presence or abundance of Cowbirds in a given area, and rates of nest parasitism for species that are Cowbird hosts.
4) Potential landscape scale metrics of habitat degradation include the identification of preferred Cowbird breeding habitats that are in close proximity to Cowbird feeding sites.
5) Species that experience Cowbird parasitism are negatively impacted through reduced reproductive success; other characteristics of avian communities do not reflect the negative impacts of parasitism.

<u>Relevance of Results to the Yellowstone River</u>
Only a few studies examined the influences of Cowbirds on riparian communities along large rivers in Montana or bordering states. Tewksbury and others examined relationships between Cowbirds and landscape characteristics surrounding cottonwood gallery forest of the Bitterroot River in Montana (Tewksbury et al. 1998, 1999, 2006) and the Snake River in Idaho (Tewksbury et al. 2006). However, other studies are relevant to the Yellowstone River system because they were located in cottonwood dominated forests along large southwestern river systems (Sechrist and Ahlers 2003, Chace 2004, Sharp and Kus 2006, Brodhead et al. 2007). Results from these studies are especially informative because they consider habitats with similar vegetation species composition and structure, and often discuss bird species that also occur along the Yellowstone River.

Results from the YRCDC Avian Study provide further evidence for the relationships between land use drivers, habitat, and the distribution of Cowbirds (Jones and Hansen 2009). Along the Yellowstone River, Cowbirds were more often present in forest habitats than other habitat types, suggesting this may be preferred breeding habitat. They were documented at 74% of the cottonwood forest study sites along the river, compared with 33% of the grassland sites and 58% of the shrub sites. Highest Cowbird abundances were reported in the western reaches of the river, and abundance declined steadily downstream. Land use was an important factor influencing Cowbird abundance in cottonwood forest; Cowbird abundance was highest at cottonwood forest sites that were closer to human settlement. Human settlements were defined as all houses and outbuildings within the floodplain boundary, and were located using 2001 aerial photo imagery. Human settlements were generally located closer to riparian habitats, and at higher densities, in the western reaches of the river. The relationship between Cowbird abundance at cottonwood forest sites and the distance to the nearest crop field was also examined; this relationship was also negative, but the correlation was weak and not significant. Crop fields were defined as any irrigated field, and did not include dryland crops or pastures. Reproductive output for nests of host species was not measured during the YRCDC Avian Study.

Twenty-seven of the 64 species documented in riparian habitat along the Yellowstone River are Cowbird host species (Table 6). Of these host species, 14 may be especially vulnerable to the negative impacts of parasitism due to either declining population trends, their status as a species of general conservation concern, or their relatively exclusive use of riparian forest habitat (Table 6). American Redstarts, Common Yellowthroats, and Orchard Orioles may be at risk because they are all experiencing declining populations and are riparian obligate species, while Black-and-white Warblers are riparian obligates and a Potential Species of Concern. Of special consideration is the Ovenbird, a Potential Species of Concern that is a riparian obligate and is experiencing declining populations.

Table 6. Yellowstone River bird species identified as Cowbird host species based on life-history characteristics and empirical studies, and conservation status for each species.

Cowbird Host Species	**Sources**	**Declining Trend**	**Species of General Conservation Concern***	**Riparian Obligate**
American Redstart	Sherry and Holmes 1997 Tewksbury et al. 1999 (Bitterroot River, MT) Hahn and Hatfield 1995	X		X
Black-and-white Warbler	Kricher 1995 Hahn and Hatfield 1995		PSOC	X
Black-headed Grosbeak	Ortega and Hill 2010 Airola 1986 Heath et al. 2010			
Brewer's Blackbird	Martin 2002			
Clay-colored Sparrow	Grant and Knapton 2012	X		
Chipping Sparrow	Middleton 1998			
Common Yellowthroat	Guzy and Ritchison 1999 Tewksbury et al. 1999 (Bitterroot River, MT) Hahn and Hatfield 1995	X		X
Dickcissel	Temple 2002		SOC	
Field Sparrow	Carey et al. 2008			
Grasshopper Sparrow	Vickery 1996			
Lark Sparrow	Martin and Parrish 2000			
Lazuli Bunting	Greene et al. 1996 Tewksbury et al. 1999 (Bitterroot River, MT)			
Least Flycatcher	Tarof and Briskie 2008			
Orchard Oriole	Scharf and Kren 2010	X		X
Ovenbird	Porneluzi et al. 2011 Hahn and Hatfield 1995	X	PSOC	X
Plumbeous Vireo	Goguen and Curson 2012 Chace et al. 2003 Airola 1986		PSOC	

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Table 6 continued.

Cowbird Host Species	Sources	Declining Trend	Species of General Conservation Concern*	Riparian Obligate
Red-eyed Vireo	Cimprich et al. 2000 Tewksbury et al. 1999 (Bitterroot River, MT) Hahn and Hatfield 1995	X		
Red-winged Blackbird	Yasukawa and Searcy 1995			
Savannah Sparrow	Wheelright and Rising 2008			
Song Sparrow	Arcese et al. 2002 Tewksbury et al. 1999 (Bitterroot River, MT) Airola 1986 Heath et al. 2010 Purcell and Verner 1999 Hahn and Hatfield 1995			X
Spotted Towhee	Greenlaw 1996 Small 2005 Hahn and Hatfield 1995			
Vesper Sparrow	Jones and Cornely 2002	X		
Warbling Vireo	Gardali and Ballard 2000 Heath et al. 2010 Tewksbury et al. 1999 (Bitterroot River, MT) Airola 1986 Purcell and Verner 1999			
Western Meadowlark	Davis and Lanyon 2008	X		
Western Wood-pewee	Bemis and Rising 1999 Heath et al. 2010 Purcell and Verner 1999			
Yellow Warbler	Lowther et al. 1999 Tewksbury et al. 1999 (Bitterroot River, MT) Airola 1986 Heath et al. 2010 Purcell and Verner 1999 Hahn and Hatfield 1995 Tewksbury et al. 2006 (Bitterroot River, MT; Snake River, ID)			X
Yellow-breasted Chat	Eckerle and Thompson 2001			X

* Species of general conservation concern are designated as either a Potential Species of Concern (PSOC) or a Species of Concern (SOC) by the Montana Natural Heritage Program (2013).

Potential Future Analyses of Avian-Habitat Relationships

This Physical Impact is unique in that much of the literature review was focused on relationships between land use drivers and the impacted habitat resource (i.e. habitat degradation from Cowbird parasitism) rather than avian-habitat relationships. With an underlying understanding of avian responses to Cowbird parasitism (i.e. lower reproductive ouput), metrics representing the distribution of Cowbirds will actually be most useful for understanding the potential impacts of land use on riparian bird communities.

Future analyses that examine relationships between land use variables and Cowbird distribution using data collected along the Yellowstone River may help to validate the relationships identified in the literature review. Avian data collected along the Yellowstone River measured Cowbird abundance, but not rates of parasitism. Cowbird abundance and rates of parasitism are often correlated (Borgmann and Morris 2010, Purcell and Verner 1999, Burhans and Thompson 2006; but see Chace et al. 2005), so measures of Cowbird abundance should be adequate for quantifying the potential impacts of land use on bird communities. Suggested analyses include the examination of relationships between Cowbird abundance and land use drivers that represent measures of human development, agriculture, and areas where livestock are present. Land use variables can be quantified using data from the Yellowstone River Land Use Mapping effort.

Riparian forest that is in close proximity to land uses that provide Cowbird feeding sites may represent a landscape scale metric of potentially degraded habitat (i.e. habitat that will likely have higher Cowbird abundance). The accuracy of this metric can be assessed using avian data that quantifies Cowbird abundance, and landscape scale habitat mapping data from the Riparian Mapping effort that identifies riparian habitat types. If Cowbird abundance is significantly higher in certain forest habitat types compared with other riparian habitats, then forest that is in close proximity to detrimental land uses may represent habitat potentially most degraded by Cowbird parasitism. See Table 7 for a description of the specific metrics and data available for these analyses. See Section '*Relevance Of Results To Cumulative Effects Analysis'* for a discussion of potential Cumulative Effects assessments.

Table 7. Specific metrics and data available for the examination of Yellowstone River avian-habitat relationships relevant to the expansion of Brown-headed Cowbirds in riparian habitats.

Metric Type	Metric	Description of Metric (Data Source)
Habitat Resource	Cowbird abundance	Average abundance of Cowbirds (Avian Data)
Land Use Driver	Distance to or density of agriculture	Herbaceous cover type that is either irrigated or not irrigated (Riparian Mapping and Land Use Mapping)
Land Use Driver	Distance to or density of human development	Urban or exurban cover types, with particular emphasis on residential cover types (Land Use Mapping)
Land Use Driver	Distance to or density of farm infrastructure	Cover type representing agricultural infrastructure, such as farmsteads, outbuildings, feedlots, or corrals (Land Use Mapping)
Habitat Resource	Riparian habitat type	Delineation of riparian habitat types (open, closed timber, shrub) in the floodplain (Riparian Mapping)

PHYSICAL IMPACT: EXPANSION OF DETRIMENTAL SPECIES – INVASIVE COMPETITORS

Non-native bird species are often detrimental because they aggressively compete with native bird species for important resources, such as food and nest sites. The European Starling is a non-native species that is abundant in riparian habitats on the Yellowstone River, documented at over 50% of survey sites in cottonwood forest (Jones and Hansen 2009). Native to Europe and Asia and introduced to North America over 100 years ago, Starlings are now found throughout the continent. They forage in open country with short-grass habitat (e.g. grazed pasture, mowed lawns), and reach highest densities in agricultural areas and areas of human settlement (Cabe 1993). Starlings place their nests inside cavities in trees; they do not excavate their own nest holes, but instead either use existing cavities or usurp cavities from other birds that do excavate.

Starlings may have a detrimental effect on populations of native cavity-nesting species. They steal cavities from birds that have already initiated nesting; those individuals then have to find or excavate a new cavity and lay another clutch. Nests initiated later in the breeding season often suffer lower reproductive output (i.e. fewer eggs laid, lower nest survival; Ingold 1989, 1994, 1996, 1998, Wiebe 2003, Fisher and Wiebe 2006). Only a few studies have empirically assessed these potential negative impacts for individual species. Three studies quantified the negative impacts of Starling competition for Northern Flickers, a cavity-nesting species that is common in riparian habitats along the Yellowstone River. In those studied populations, 7% (Ingold 1989), 5-10% (Fisher and Wiebe 2006), and 68% (Ingold 1998) of Flicker nests were usurped by Starlings. Red-headed Woodpeckers, a cavity-nesting species found in riparian habitats of the lower reaches of the Yellowstone River, may also be negatively impacted by competition with Starlings. In two studies, 7-15% of Red-headed Woodpecker nests were stolen by Starlings, and reproductive output was lower for those individuals that re-nested as a result of usurpation (Ingold 1994, 1989). However, Red-headed Woodpeckers generally avoid large scale impacts of Starling competition because they initiate nesting later in the breeding season than do Starlings and other native cavity-nesting species (Cabe 1993).

Although reproductive output may be lower for individuals that experience competition with Starlings for nesting cavities, the overall impacts to native bird populations are not well-understood. Koenig (2003) used Breeding Bird Survey data to examine relationships between the invasion of Starlings across North America and population trends for native cavity-nesting species, and the analyses found no evidence for a negative effect of Starling competition on any species. Many factors may potentially influence the magnitude of the impact Starlings have on native bird species (e.g. the local availability of nest cavities or the abundance of native cavity-nesting species), and these impacts are difficult to generalize. Consequently, I will not expand further on the discussion of impacts or potential analyses for this Physical Impact. However, it is important to note that Red-headed Woodpeckers are a Species of Concern in Montana, and competition with Starlings has been suggested as a potential factor in their population declines (Smith et al. 2000).

PHYSICAL IMPACT: SPREAD OF INVASIVE PLANT SPECIES

Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix* spp.) are two of the most invasive exotic plants to become naturalized in riparian areas of the West. Russian olive trees have been planted as windbreaks in Montana since at least the 1950's (Lesica and Miles 2001), and Russian olive is now distributed along the entire Yellowstone River, its tributaries, and most other major river systems in Montana (Combs and Potter 2011, Katz and Shafroth 2003). Saltcedar was first documented in Montana in the 1960's, and has since expanded along the Yellowstone River east of Big Timber, as well as along other major waterways in eastern Montana (Jacobs and Sing 2007, Grubb et al. 2010, Sexton et al. 2006). Both Russian olive and saltcedar have the potential to outcompete and replace native species, and consequently may alter the composition and structure of riparian plant communities (Grubb et al. 2010, Lesica and Miles 1999, Sexton et al. 2006). Habitats dominated by Russian olive and saltcedar may not provide the same food and nesting resources that are provided by native habitats, resulting in altered characteristics of bird communities and potential negative impacts for certain bird species. Following is a summary of the influences of Russian olive and saltcedar on native bird communities in riparian areas of the West.

<u>Russian Olive</u>

Relatively few studies have evaluated the effects of Russian olive expansion into riparian habitats on bird communities; 7 studies are included in this review. Russian olive is a tall shrub or small tree that grows in monotypic stands or in the understory of cottonwood forest (Lesica and Miles 1999). Structural complexity is greater in native cottonwood habitats compared with monotypic stands of Russian olive, with Russian olive stands providing less canopy cover and fewer large trees (Knopf and Olson 1984, Noson et al. 2008). Consequently, bird species richness and total bird abundance are often lower in stands of Russian olive when compared with native habitats (Knopf and Olson 1984, Yong and Finch 2002, Brown 1990, Noson et al. 2008, Slater 2006).

However, conclusions about the effects of Russian olive on characteristics of bird communities are often mixed. Cottonwood forest habitat with Russian olive present in the understory may provide equal or greater structural complexity than pure native stands (Yong and Finch 2002) and bird species richness is often higher in these habitats (Yong and Finch 2002, Slater 2006, Fischer et al. 2012). Furthermore, different species respond to the presence of Russian olive in different ways. Many species that forage and nest in the shrub strata of riparian forest, such as Yellow-breasted Chats, consistently use, and may even prefer, habitats with Russian olive (Stoleson and Finch 2001, Slater 2006, Noson et al. 2008). Conversely, riparian habitats dominated by Russian olive usually support fewer species that nest and forage in the canopy strata (Knopf and Olson 1984, Noson et al. 2008), and cavity-nesting and bark-gleaning species that depend upon large trees are consistently absent (Knopf and Olson 1984, Stoleson and Finch 2001, Noson et al. 2008, Slater 2006, Brown 1990. Fischer et al. 2012).

Information is not sufficient to assess whether native habitats offer higher quality breeding opportunities for riparian birds. Only one study investigated reproductive success in Russian olive habitats compared with native habitats, and no differences were evident (Stoleson and Finch 2001). Most riparian bird species are insectivorous, particularly during the breeding season when energy demands are highest, and food availability is a critical component of habitat quality. The presence of exotic plant species may alter characteristics of insect communities in riparian habitats. Limited information suggests that native cottonwood and willow may provide higher abundance and richness of insects than Russian olive (Yong and Crawford 1997, Pendleton et al. 2011), and in one study where foraging behavior was observed, omnivorous species were more abundant in Russian olive plants than insectivores (Slater 2006).

Saltcedar

All of the studies reviewed that evaluated the impacts of saltcedar invasion on bird communities occurred in the southwestern US where saltcedar is a dominant component of riparian plant communities. Saltcedar is a tall shrub or small tree that usually establishes in monotypic stands on alluvial surfaces (Sexton et al. 2006). Habitats dominated by saltcedar lack large trees and high canopy cover, and are relatively structurally simple compared to native cottonwood forest (Shanahan et al. 2011, Brand et al. 2008, Slater 2006). Results from studies investigating the relationships between the presence of saltcedar and characteristics of bird communities are mixed (Sogge et al. 2008). Three studies reported higher bird species richness in native habitat compared with saltcedar (Brand et al. 2008, Anderson et al. 1977, VanRiper et al. 2008), while four studies reported no differences or higher richness in saltcedar habitats (Shanahan et al. 2011, Ellis 1995, Hunter et al. 1988, Fleishman et al. 2003). However, more unique, riparian specialist species were reported using native habitats than habitats dominated by saltcedar (Brand et al. 2008, Ellis 1995, Hunter et al. 1988), and cavity-nesting species were consistently absent from saltcedar stands (Anderson et al. 1977, Ellis 1995, Slater 2006).

As with Russian olive, information about whether native habitats offer higher quality breeding opportunities for riparian birds is sparse. The breeding ecology of the federally endangered Southwestern Willow Flycatcher has been studied extensively in saltcedar habitats, and few negative impacts on reproductive success are evident (Sogge et al. 2008). Brand et al. (2010) reported that breeding success was higher for shrub-nesting insectivores in native habitat compared with saltcedar, but no differences were observed for other species. However, habitat quality may be negatively impacted through the reduced availability of food resources; saltcedar often provides less diverse and abundant insect communities than native riparian habitats (Shanahan et al. 2011, Durst et al. 2008, Pendleton et al. 2011, DeLay et al. 1999; but see Mund-Meyerson 1998, Ellis et al. 2000).

Relevance to the Yellowstone River

Little information exists about the impacts of invasive plants on riparian bird communities along the Yellowstone River. During the YRCDC Avian Study (Jones and Hansen 2009), Russian olive was documented as a dominant component of the understory in cottonwood forest habitats. Limited analyses were conducted evaluating relationships between the density of Russian olive and various bird community characteristics. There was no evidence for an effect of Russian olive density on bird species richness. The abundances of three individual bird species were negatively correlated with Russian olive density, but abundances for these species were also negatively correlated with the density of tall native shrubs, suggesting a response to habitat structure in general, and not Russian olive specifically. Few saltcedar habitats were sampled during the YRCDC Avian Study, and consequently no analyses were conducted evaluating the influences of saltcedar on bird communities.

Few data exist for quantifying relationships between the spread of invasive plant species and riparian bird communities along the Yellowstone River. The distribution of Russian olive was mapped for all counties along the river corridor (Combs and Potter 2011), but this dataset represents only monotypic stands and not Russian olive growing in the understory of cottonwood forest, which is a significant component of riparian habitat for birds (Jones and Hansen 2009). Saltcedar has been mapped for part of the corridor, but extensive mapping efforts have not yet been completed. Consequently, I will not expand further on the discussion of impacts or potential future analyses for this Physical Impact.

However, it is important to emphasize that the invasion of Russian olive and saltcedar in riparian areas of western rivers is potentially enhanced when natural hydrologic regimes are altered. Both species are better adapted than native riparian plants to establish and reproduce in conditions where flood disturbance is minimized (Katz and Shafroth 2003, Sexton et al. 2006, Glenn and Nagler 2005). Consequently, the construction of armor along the banks of the Yellowstone River for the protection of particular land uses could enhance conditions for the spread of these exotic species by restricting natural channel migration and decreasing the area of the floodplain impacted by flooding. Furthermore, studies reported that cavity-nesting species were consistently absent from stands of both Russian olive and saltcedar. The replacement of native cottonwood communities along the Yellowstone River would almost certainly be detrimental for these native bird species. This is an important consideration for Red-headed Woodpeckers, a Species of Concern in Montana that depends upon large cottonwood trees for foraging and nesting habitat (Slater 2006, Gutzwiller and Anderson 1987, Smith et al. 2000).

PHYSICAL IMPACT: DIRECT ADULT OR NEST MORTALITY

Land use within the riparian zone of the Yellowstone River may cause direct mortality to birds and nests, resulting in the degradation of riparian habitats. Agricultural practices such as mowing of riparian lowland hayfields and application of pesticides that filter into riparian habitats may alter quality of habitat for riparian bird species.

Mowing

The mowing of hayfields in the riparian zone may be detrimental to riparian bird populations if it occurs during the breeding season. Many grassland-dependent riparian bird species use hayfields as crucial breeding habitat from late May to early July in Montana. Nests in hayfields are located on the ground, so that nests and birds are extremely susceptible to mortality from mowing machines (McMaster et al. 2005, Perlut et al. 2006, Dale et al. 1997, Nocera et al. 2005, Bollinger et al. 1990). Furthermore, nests that are not destroyed are usually more exposed after mowing, often leading to abandonment and increased risk of predation (Bollinger et al. 1990). Consequently, mowing of hayfields during the breeding season results in lower reproductive output (Gruebler et al. 2012, Kruk et al. 1997, Perlut et al. 2006, Broyer 2011, Bollinger et al. 1990) and increased adult and juvenile mortality (Gruebler et al. 2008, Bollinger et al. 1990), and many species experience declines in abundance at a site after mowing has occurred (Frawley and Best 1991).

Negative impacts to grassland-dependent birds may have increased in recent decades due to changes in agricultural practices that have resulted in earlier and more frequent mowing of hayfields (Rodenhouse et al. 1993). Renesting after initial nest failure from mowing is often unsuccessful because the interval between mowing cycles is too short to accommodate the nesting period length of most bird species (Bollinger et al. 1990, Perlut et al. 2006). Earlier and more frequent mowing of hayfields has been correlated with population declines of many grassland species (Gruebler et al. 2008, Bollinger et al. 1990, Peterjohn and Sauer 1999, Perlut et al. 2008, Herkert 1997).

Relatively few studies have specifically examined the effects of mowing on birds, and none of the studies included in this review were located in the West. However, those studies that do exist have demonstrated significant negative effects of mowing on riparian grassland bird communities. Many of the species impacted by mowing in other regions of North America have been documented using riparian habitats along the Yellowstone River. For example, Savannah Sparrows, recorded at 40% of riparian grassland sites sampled along the Yellowstone River (Jones and Hansen 2009), have been reported to suffer severe nest loss (99%; Perlut et al. 2006) and significantly reduced reproductive output (80% decline; Dale et al. 1997) after mowing occurred in hayfields used as breeding habitat. Similarly, Boblinks have been reported to experience total nest failure and high rates of juvenile mortality as a result of mowing (Perlut et al. 2006, Bollinger et al. 1990). There is evidence that populations of both species are significantly influenced by the effects of lower productivity and high mortality from mowing (Perlut et al. 2008, Bollinger et al. 1990). For Bobolinks, mowing results in rates of reproductive output that are low enough to cause population declines (Bollinger et al. 1990, Perlut et al. 2008).

No data exist for quantifying relationships between mowing and grassland bird communities along the Yellowstone River. Consequently, I will not expand further on the discussion of impacts or potential future analyses for this Physical Impact. However, mowing of riparian habitats along the Yellowstone River could be detrimental for many species of grassland birds that depend upon these habitats for breeding. Potential impacts to Bobolinks, a Species of Concern in Montana that depends upon lowland riparian grasslands and hayfields, deserve special consideration. Mowing during the breeding season has been suggested as one of the most important factors influencing population declines for this species (Herkert 1997).

<u>Pesticide and Herbicide Use</u>

The application of pesticides and herbicides to agricultural fields potentially impacts riparian bird populations in many ways. Direct mortality or physiological impairment may occur when birds ingest toxic levels of pesticides, and the application of pesticides may negatively impact survival and reproductive output by reducing the abundance of food resources (Gard and Hooper 1995, Gard et al. 1993, Hart et al. 2006). Herbicides are generally non-toxic to birds, but may impact some species through the alteration of habitat and food resources (Morrison and Meslow 1983).

Very little information is available that describes the effects of pesticides on populations of wild birds, particularly migratory songbirds that are generally of greatest conservation and management concern (Gard and Hooper 1995). Existing studies report varying impacts based on the type of pesticide, amounts ingested by individual birds, and the species of bird affected, and are focused on farmland birds that nest and forage in cropland, not riparian habitats. It is unclear to what degree pesticides get disseminated into riparian habitats from agricultural crops. Consequently, it is difficult to identify general relationships that may exist between the use of agricultural pesticides and riparian bird communities that may be relevant to the Yellowstone River, and I will not discuss potential future analyses for this Physical Impact.

<u>RELEVANCE OF RESULTS TO CUMULATIVE EFFECTS ANALYSIS</u>

Knowledge about the relationships between land use drivers, habitat resources, and avian communities allows for inference about how characteristics of land use and habitat potentially impact riparian birds along the Yellowstone River. If relationships discussed in the literature review are validated using land use, habitat, and avian data collected along the Yellowstone River, greater confidence is provided for results and conclusions from Cumulative Effects analyses. Table 8 summarizes the relationships identified between land use drivers, habitat resources, and avian communities for the three main Physical Impacts, as well as the metrics available for quantifying these relationships at the reach scale. Eventually, knowledge of these relationships will facilitate the incorporation of impacts to bird communities into Cumulative Effects analyses.

The four focal avian Species of Concern were impacted by land use and changes to habitat resources in various ways. Below is a summary of impacts for each species. Additionally, Table 9 includes a summary of reach-scale metrics of habitat change that are important for each species and that may be especially relevant for Cumulative Effects analysis.

<u>Black-billed Cuckoo</u>
Black-billed Cuckoo's depend upon relatively large tracts of riparian forest with a dense understory shrub layer, and are a forest specialist and understory specialist species. Cuckoos are potentially negatively impacted by the **construction of bank armor**, **livestock grazing**, and the **conversion of riparian habitat to agriculture** that result in the fragmentation and loss of forest habitat and a decline in structurally complex forest habitats. Cuckoo's were identified as a species that would be potentially impacted by two of the three main Physical Impacts, suggesting that Cuckoo's may deserve special consideration when assessing Cumulative Effects on riparian birds.

<u>Bobolink</u>
Boblinks are a grassland dependent species that nests in riparian meadows and hayfields. Along the Yellowstone River, this species is potentially negatively impacted by riparian management activities that include **mowing of meadows and hayfields** during the breeding season (late May to early July). Furthermore, throughout their range Bobolinks are significantly impacted by the conversion of riparian grassland habitats to more intensive land uses (e.g. cropland; Dechant et al. 2003, Martin and Gavin 1995).

<u>Red-headed Woodpecker</u>
Red-headed Woodpeckers depend upon riparian forest with large trees and snags. In riparian habitats of the Yellowstone River, this species is possibly negatively impacted by the **expansion of European Starlings, an invasive species** that competes with native woodpeckers for nesting sites and is associated with agricultural and residential areas. Furthermore, Red-headed Woodpeckers are potentially impacted by the **introduction and expansion of invasive plant communities** that do not provide the large trees and snags needed for nesting. Across its range, the single most important management issue for this species is the retention of habitat that contains large live and standing dead trees (Smith et al. 2000).

<u>Least Tern</u>
None of the Physical Impacts discussed in this review were relevant to Least Terns. However, changes in habitat and food availability along rivers used by Least Terns have been suggested as main factors in

the decline of this species (Atkinson and Dood 2006). Least Terns nest on unvegetated sandbars and shorelines, and forage on small fish in shallow water habitats. Breeding Least Terns have been documented along the Yellowstone River downstream from Miles City. Major threats to breeding habitat include **channelization and bank stabilization** projects that contribute to the loss and degradation of sandbars and shorelines used for nesting, and shallow, slow-velocity aquatic habitats used for foraging.

Table 8. Relationships and reach-scale metrics identified for land use drivers, habitat resources, and avian responses for the three focal Physical Impacts reviewed in the literature assessment. The four focal Species of Concern are emphasized in bold type.

Physical Impact	Land Use Drivers and Impacts to Habitat Resources	Reach-Scale Metrics of Land Use Drivers	Reach-Scale Metrics of Impacted Habitat Resources	Relationships between Habitat Resources and Avian Community	Reach-Scale Metrics of Avian Responses

Loss of cottonwood forest habitat	Conversion of riparian habitat to agricultural land uses reduces the area of cottonwood forest habitat	Total and % area of agricultural land uses	Total area of closed and open timber
			
			Average and maximum patch size of closed and open timber
			
			Average width of riparian forest on each side of the river
			
			Area of riparian turnover (woody vegetation to channel and vice versa)
				Avian responses negatively correlated with decreasing area of forest cover, forest width, and patch size:
				• Total species richness
				• Species richness and abundance of forest specialist species
				• Abundances of individual forest specialist species, including these species of conservation concern:
				  • *American Redstart* (declining population, riparian obligate)
				  • *Black-capped Chickadee, Red-eyed Vireo* (declining populations)
				  • *Black-and-white Warbler* (Montana Potential Species of Concern, riparian obligate)
				  • *Gray Catbird, Yellow Warbler* (riparian obligates)
				  • *Ovenbird* (declining population, Montana Potential Species of Concern, riparian obligate)
				  • ***Black-billed Cuckoo*** (declining population, Montana Species of Concern, riparian obligate)
					Average species richness and average richness of forest species for cottonwood forest sites sampled in the reach or region
					
					Occurrence of individual forest specialist species of conservation concern observed in the reach or region, % of sites where observed

		Total and % area of riparian forest habitat converted to agricultural land uses			
	Livestock grazing of cottonwood seedlings leads to long-term declines in cottonwood regeneration and reduces the area of forest habitat	No data available to quantify livestock grazing intensity in riparian habitats			
	The construction of armor along the banks of the river restricts natural channel migration and decreases riparian turnover and the creation of new forest habitat	Total length and % of physical features, length and % of features protecting different land uses			
		Total and % area restricted by physical features			
		Braiding parameter			
		Acres of in-channel gravel bars (per river mile)			

Table 8 continued.

<table>
<tr><th>Physical Impact</th><th>Land Use Drivers and Impacts to Habitat Resources</th><th>Reach-Scale Metrics of Land Use Drivers</th><th>Reach-Scale Metrics of Impacted Habitat Resources</th><th>Relationships between Habitat Resources and Avian Community</th><th>Reach-Scale Metrics of Avian Responses</th></tr>
<tr><td rowspan="5">Loss of structurally complex forest habitat</td><td>Livestock grazing in cottonwood forest leads to a decline in the density of understory and midstory vegetation, and results in more structurally simple forest habitat</td><td>No data available to quantify livestock grazing intensity in riparian habitats</td><td rowspan="5">Total area of closed (structurally complex) and open (structurally simple) timber

Area of riparian turnover (woody vegetation to channel and vice versa)</td><td rowspan="5">Avian responses that experience declines with the loss of structural complexity of riparian forest habitat:
• Total species richness
• Species richness and abundance of understory specialist species
• Abundances of individual understory specialist species, including these species of conservation concern:
  • American Redstart, Common Yellowthroat (declining populations, riparian obligates)
  • Gray Catbird, Song Sparrow, Yellow Warbler, Yellow-breasted Chat (riparian obligates)
  • Black-billed Cuckoo (declining population, Montana Species of Concern, riparian obligate, Partners in Flight Watchlist Species)</td><td rowspan="5">Average species richness and average richness of understory species for cottonwood forest sites sampled in the reach or region

Occurrence of individual understory specialist species of conservation concern observed in the reach or region, % of sites where observed</td></tr>
<tr><td rowspan="4">The construction of armor along the banks of the river restricts natural channel migration, decreases riparian turnover, and leads to a loss of structurally complex early and mid-successional cottonwood forest habitat types in the floodplain</td><td>Total length and % of physical features, length and % of features protecting different land uses</td></tr>
<tr><td>Total and % area restricted by physical features</td></tr>
<tr><td>Braiding parameter</td></tr>
<tr><td>Acres of in-channel gravel bars (per river mile)</td></tr>
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Table 8 continued.

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<tr><th>Physical Impact</th><th>Land Use Drivers and Impacts to Habitat Resources</th><th>Reach-Scale Metrics of Land Use Drivers</th><th>Reach-Scale Metrics of Impacted Habitat Resources</th><th>Relationships between Habitat Resources and Avian Community</th><th>Reach-Scale Metrics of Avian Responses</th></tr>
<tr><td rowspan="6">Expansion of detrimental species: Brown-headed Cowbirds</td><td rowspan="2">Presence of livestock results in an increase in cowbird feeding opportunities close to the riparian zone, and a subsequent increase in the abundance of cowbirds in riparian habitats</td><td>Total and % area or density of agricultural infrastructure</td><td rowspan="6">Total area of riparian forest (closed and open timber) within 1 kilometer of particular land use drivers

Average cowbird abundance in riparian forest</td><td rowspan="6">Avian species that may be most negatively impacted by cowbird parasitism:

• These cowbird host species of conservation concern:
• American Redstart, Common Yellowthroat, Orchard Oriole (declining populations, riparian obligates)
• Song Sparrow, Yellow Warbler, Yellow- breasted Chat (riparian obligates)
• Clay-colored Sparrow, Red-eyed Vireo, Vesper Sparrow, Western Meadowlark (declining populations)
• Dickcissel, Plumbeous Vireo (Montana Potential Species of Concern)
• Black-and-white Warbler (Montana Potential Species of Concern, riparian obligate)
• Ovenbird (declining population, Montana Potential Species of Concern, riparian obligate)</td><td rowspan="6">Average richness of cowbird host species for cottonwood forest sites sampled in the reach or region

Occurrence of individual cowbird host species of conservation concern observed in the reach or region, % of sites where observed</td></tr>
<tr><td>Total and % area of non-irrigated herbaceous cover type (i.e. potential pastureland)</td></tr>
<tr><td rowspan="2">Presence of residential areas results in an increase in cowbird feeding opportunities associated with lawns, corrals, and other open habitats, and a subsequent increase in the abundance of cowbirds in nearby riparian habitats</td><td>Total and % area or density of agricultural infrastructure (i.e. residential farmsteads)</td></tr>
<tr><td>% area or density of urban and exurban residential cover types</td></tr>
<tr><td rowspan="2">Presence of agricultural lands and associated farmsteads and infrastructure results in an increase in cowbird feeding sites, and a subsequent increase in the abundance of cowbirds in nearby riparian habitats</td><td>% area irrigated and non-irrigated herbaceous cover type</td></tr>
<tr><td>% area or density of agricultural infrastructure</td></tr>
</table>

Table 9. Reach-scale metrics of habitat change that are important for each of the focal species of concern, and Yellowstone River reaches where they were documented during the Avian Study conducted in 2006 and 2007 (Jones and Hansen 2009).

Species of Concern	Reach-Scale Metric of Habitat Change (Data Source)	River Reaches Where Species Documented During Avian Study
Black-billed Cuckoo	Total and percent area closed canopy forest; average, minimum, maximum patch size for closed canopy forest (Riparian mapping)	B1, D12
Bobolink	Area of agricultural land converted from hayland/pasture to irrigated or tilled (Land use mapping)	A7, A11, A17, C7, C9, D12
Red-headed Woodpecker	Total and percent area closed canopy and open canopy forest (Riparian mapping)	B7, B8, C3, C7, C9, D5, D10, D11, D12
Least Tern	Braiding parameter, acres of in-channel gravel or sandbars per river mile, presence of side channels (Geomorphology)	Not sampled during Avian Study; Documented at various reaches downstream of Miles City in Atkinson and Dood (2006)

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Appendix 1. Riparian breeding bird species detected during point count surveys conducted along the Yellowstone River in the summers of 2006 and 2007 (Jones and Hansen 2009). Non-target species (ducks, raptors, upland gamebirds, and shorebirds) are excluded. Species included in each of the two habitat guilds ('Forest Specialist' and 'Understory Specialist') are reported, as well as species designated as 'Riparian Obligates' and 'Declining Species'. The conservation status is also summarized for each of the species when appropriate.

Common Name	Scientific Name	Habitat Guild Associations		Riparian Obligate[3]	Declining Species[4]	Species of General Conservation Concern[5]
		Forest Specialist[1]	Understory Specialist[2]			
American Crow	*Corvus brachyrhynchos*					
American Goldfinch	*Carduelis tristis*		X			
American Redstart	*Setophaga ruticilla*	X	X	X	X	
American Robin	*Turdus migratorius*					
Baltimore Oriole	*Icterus galbula*			X	X	
Barn Swallow	*Hirundo rustica*					
Black-and-white Warbler	*Mniotilta varia*	X		X		PSOC
Black-billed Cuckoo	*Coccyzus erythropthalmus*	X	X	X	X	SOC, PIF Watchlist, MTFWP Moderate Conservation Need
Black-billed Magpie	*Pica hudsonia*					
Black-capped Chickadee	*Poecile atricapillus*	X			X	
Black-headed Grosbeak	*Pheucticus melanocephalus*	X	X			
Blue Jay	*Cyanocitta cristata*					
Bobolink	*Dolichonyx oryzivorus*					SOC, BLM Sensitive
Brewers Blackbird	*Euphagus cyanocephalus*					
Brown Thrasher	*Toxostoma rufum*				X	
Brown-headed Cowbird	*Molothrus ater*					
Bullock's Oriole	*Icterus bullockii*			X		
Cedar Waxwing	*Bombycilla cedrorum*	X	X			

[1] Forest specialist species prefer habitats comprised of extensive forest.
[2] Understory specialist species forage or nest in the shrub strata of the forest, and depend upon structurally complex habitats.
[3] Riparian obligates are species largely dependent on riparian habitats in the western US.
[4] Declining species are species experiencing significantly negative long-term (1966-2011) population trends reported from the Breeding Bird Survey.
[5] For species of general conservation concern, conservation status is reported for The Montana Natural Heritage Program ('Potential Species of Concern (PSOC)' or 'Species of Concern (SOC)'), Partners in Flight (PIF Watchlist Species), Montana Fish Wildlife and Parks (MTFWP), and Bureau of Land Management (BLM).
*Not observed in riparian habitats, but included because physical impacts of land use potentially affect this species along the Yellowstone River.

Appendix 1 continued.

Common Name	**Scientific Name**	**Habitat Guild Associations**		**Riparian Obligate[3]**	**Declining Species[4]**	**Species of General Conservation Concern[5]**
		Forest Specialist[1]	**Understory Specialist[2]**			
Chimney Swift	*Chaetura pelagica*				X	PSOC
Chipping Sparrow	*Spizella passerina*					
Clay-colored sparrow	*Spizella pallida*				X	
Cliff Swallow	*Petrochelidon pyrrhonota*					
Common Grackle	*Quiscalus quiscula*					
Common Yellowthroat	*Geothlypis trichas*		X	X	X	
Dickcissel	*Spiza americana*					PSOC
Downy Woodpecker	*Picoides pubescens*	X				
Eastern Kingbird	*Tyrannus tyrannus*				X	
European Starling	*Sturnus vulgaris*				X	
Field Sparrow	*Spizella pusilla*					
Grasshopper Sparrow	*Ammodramus savannarum*					
Gray Catbird	*Dumetella carolinensis*	X	X	X		
Hairy Woodpecker	*Picoides villosus*	X				
House Wren	*Troglodytes aedon*	X				
Lark Sparrow	*Chondestes grammacus*					
Lazuli Bunting	*Passerina amoena*		X			
Least Flycatcher	*Empidonax minimus*	X				
Least Tern*	*Sterna antillarum*					SOC, Federally Endangered, PIF Watchlist, MTFWP Greatest Conservation Need

[1] Forest specialist species prefer habitats comprised of extensive forest.
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[3] Riparian obligates are species largely dependent on riparian habitats in the western US.
[4] Declining species are species experiencing significantly negative long-term (1966-2011) population trends reported from the Breeding Bird Survey.
[5] For species of general conservation concern, conservation status is reported for The Montana Natural Heritage Program ('Potential Species of Concern (PSOC)' or 'Species of Concern (SOC)'), Partners in Flight (PIF Watchlist Species), Montana Fish Wildlife and Parks (MTFWP), and Bureau of Land Management (BLM).
*Not observed in riparian habitats, but included because physical impacts of land use potentially affect this species along the Yellowstone River.

Appendix 1 continued.

Common Name	**Scientific Name**	**Habitat Guild Associations**		**Riparian Obligate[3]**	**Declining Species[4]**	**Species of General Conservation Concern[5]**
		Forest Specialist[1]	**Understory Specialist[2]**			
Mountain Bluebird	*Sialia currucoides*					
Mourning Dove	*Zenaida macroura*				X	
Northern Flicker	*Colaptes auratus*				X	
Orchard Oriole	*Icterus spurius*			X	X	
Ovenbird	*Seiurus aurocapilla*	X		X	X	PSOC
Plumbeous Vireo	*Vireo plumbeous*	X				PSOC
Red-eyed Vireo	*Vireo olivaceous*	X			X	
Red-headed Woodpecker	*Melanerpes erythrocephalus*				X	SOC, PIF Watchlist, MTFWP Moderate Conservation Need, BLM Sensitive
Red-naped Sapsucker	*Sphyrapicus nuchalis*					
Red-winged Blackbird	*Agelaius phoeniceus*					
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	X				
Savannah Sparrow	*Passerculus sandwichensis*					
Song Sparrow	*Melospiza melodia*		X	X		
Spotted Towhee	*Pipilo maculatus*		X			
Swainson's Thrush	*Catharus ustulatus*					
Tree Swallow	*Tachycineta bicolor*					
Vesper Sparrow	*Pooecetes gramineus*				X	
Violet-green Swallow	*Tachycineta thalassina*					
Warbling Vireo	*Vireo gilvus*					
Western Kingbird	*Tyrannus verticalis*					
Western Meadowlark	*Sturnella neglecta*				X	

[1] Forest specialist species prefer habitats comprised of extensive forest.
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[3] Riparian obligates are species largely dependent on riparian habitats in the western US.
[4] Declining species are species experiencing significantly negative long-term (1966-2011) population trends reported from the Breeding Bird Survey.
[5] For species of general conservation concern, conservation status is reported for The Montana Natural Heritage Program ('Potential Species of Concern (PSOC)' or 'Species of Concern (SOC)'), Partners in Flight (PIF Watchlist Species), Montana Fish Wildlife and Parks (MTFWP), and Bureau of Land Management (BLM).
*Not observed in riparian habitats, but included because physical impacts of land use potentially affect this species along the Yellowstone River.

Appendix 1 continued.

Common Name	Scientific Name	Habitat Guild Associations		Riparian Obligate[3]	Declining Species[4]	Species of General Conservation Concern[5]
		Forest Specialist[1]	Understory Specialist[2]			
Western Wood-pewee	*Contopus sordidulous*	X				
White-breasted Nuthatch	*Sitta carolinensis*	X				
White-throated Swift	*Aeronautes saxatalis*					
Yellow Warbler	*Dendroica petechia*	X	X	X		
Yellow-bellied Sapsucker	*Sphyrapicus varius*					
Yellow-breasted Chat	*Icteria virens*		X	X		
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*					

[1] Forest specialist species prefer habitats comprised of extensive forest.
[2] Understory specialist species forage or nest in the shrub strata of the forest, and depend upon structurally complex habitats.
[3] Riparian obligates are species largely dependent on riparian habitats in the western US.
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*Not observed in riparian habitats, but included because physical impacts of land use potentially affect this species along the Yellowstone River.

Appendix 2. Relationships identified between changes in habitat resources and riparian avian communities when the extent of cottonwood forest habitat declines as a result of land use activities. The specific relationships (i.e. 'Direction of Response') between metrics quantifying the habitat resource and avian response are reported, as well as citations supporting these relationships. Citations followed by (*) indicate studies conducted in western North America.

Physical Impact	Habitat Resource Metric	Avian Response Metric	Direction of Response	Citations
Loss of cottonwood forest habitat	Area of forest cover	Species richness	+	Rottenborn 1999*, Saab 1999*, Tewksbury et al. 2002*, Hennings and Edge 2003*, Gentry et al. 2006*
		Total bird abundance	+	Tewksbury et al. 2002*
			-	Tewksbury et al. 2002*, Hennings and Edge 2003*
		Richness or abundance of forest specialist species	+	Perkins et al. 2003*
		Richness or abundance of riparian obligate species	+	Rottenborn 1999*
	Riparian forest width	Species richness	+	Stauffer and Best 1980, Kilgo et al. 1998, Peak and Thompson 2006, Cooke and Zack 2008*
			-	Sallabanks et al. 2000
		Total bird abundance	+	Conner et al. 2004, Cooke and Zack 2008*
			-	Kilgo et al. 1998
		Richness or abundance of forest specialist species	+	Kilgo et al. 1998, Peak and Thompson 2006

Appendix 2 continued.

Physical Impact	Habitat Resource Metric	Avian Response Metric	Direction of Response	Citations
Loss of cottonwood forest habitat	Riparian forest width	Richness or abundance of riparian obligate species	+	Cooke and Zack 2008*, 2009*
	Patch size	Species richness	+	Saab 1999*
		Richness or abundance of forest specialist species	+	Davidson and Knight 2001*
		Richness or abundance of riparian obligate species	+	Dobkin and Wilcox 1986*
		Predation or parasitism	None	Heltzel and Earnst 2006*, Peak et al. 2004, Tewksbury et al. 1998*, Fletcher 2009*, Morgan et al. 2007*
	Distance to edge	Species richness	None	Miller et al. 2004, Sallabanks et al. 2000
		Predation or parasitism	None	Gentry et al. 2006*, Heltzel and Earnst 2006*, Peak et al. 2004, Tewksbury et al. 1998*, Davidson and Knight 2001*
			-	Sharp and Kus 2006*

Appendix 3. Relationships identified between changes in habitat resources and riparian avian communities when the structural complexity of cottonwood forest habitat declines as a result of land use activities. The specific relationships (i.e. 'Direction of Response') between metrics quantifying the habitat resources and avian responses are reported, as well as citations supporting these relationships. Citations followed by (*) denote studies that simultaneously examined the effects of grazing on habitat structure and bird communities.

Physical Impact	Habitat Resource Metric	Avian Response Metric	Direction of Response	Citations
Decline in the structural complexity of forest habitat	Density of understory vegetation	Species richness	+	Walcheck 1970, Anderson and Ohmart 1977, Fleishman et al. 2003, Merritt and Bateman 2012, Kilgo et al. 1998, Taylor 1986*, Martin and McIntyre 2007*, Tewksbury et al. 2002*, Nelson et al. 2011*
		Richness or abundance of understory species	+	Saab 1998*, Scott et al. 2003, White 2011, Bock et al. 1993 (Review)*, Krueper et al. 2003*, Earnst et al. 2005*, 2012*, Martin and Possingham 2005*, Mosconi and Hutto 1982*, Martin and McIntyre 2007*, Wales 2001 (Review)*, Tewksbury et al. 2002*, Saab et al. 1995 (Review)*, Ammon and Stacey 1997*, Walsberg 2005*
		Total bird abundance	+	Krueper et al. 2003*, Earnst et al. 2012*, Taylor 1986*, Tewksbury et al. 2002*, Nelson et al. 2011*
	Structurally complex habitat types	Species richness	+	Finch 1989, Farley et al. 1994, Melhop and Lynch 1986, Rumble and Gobeille 2004, Jones and Hansen 2009, Scott et al. 2003*
		Richness or abundance of understory species	+	Farley et al. 1994, Rumble and Gobeille 2004, Jones and Hansen 2009, Scott et al. 2003*

Appendix 4. Relationships identified between land use drivers and habitat resources when land use activities result in the expansion of Brown-headed Cowbirds into riparian habitats. For this Physical Impact, habitat resources are measures of habitat degradation by Cowbird parasitism. The specific relationships (i.e. 'Direction of Response') between metrics quantifying the land use drivers and habitat resources are reported, as well as citations supporting these relationships.

Physical Impact	Land Use Driver Metric	Habitat Resource Metric	Direction of Response	Citations
Expansion of detrimental species: Brown-headed Cowbirds	Distance to nearest residential, urban, or exurban area	Rate of nest parasitism	-	Borgmann and Morrison 2010, Chace et al. 2003
		Cowbird abundance	-	Young and Hutto 1999, Borgmann and Morrison 2010, Chace et al. 2003
	Area of residential, urban, or exurban in landscape	Rate of nest parasitism	+	Burhans and Thompson 2006, Airola 1986, Tewksbury et al. 2006, Tewksbury et al. 1998
		Cowbird abundance	+	Burhans and Thompson 2006, Coker and Capen 1995
	Distance to nearest agriculture (cropland, pasture)	Cowbird abundance	-	Tewksbury et al. 1999, Young and Hutto 1999, Coker and Capen 1995
	Area of agriculture (cropland, pasture) in surrounding landscape	Rate of nest parasitism	None	Tewksbury et al. 2006
		Cowbird abundance	+	Stribley and Haufler 1999, Coker and Capen 1995
	Distance to nearest livestock area	Rate of nest parasitism	-	Goguen and Mathews 2000, Kostecke et al. 2003, Brodhead et al. 2007, Borgmann and Morrison 2010, Airola 1986, Purcell and Verner 1999
		Cowbird abundance	-	Goguen and Mathews 2000, Verner and Ritter 1983, Borgmann and Morrison 2010, Coker and Capen 1995
			None	Kostecke et al. 2003
	Density of livestock areas in landscape	Cowbird abundance	+	Coker and Capen 1995