Scientific Recommendations on the Size of Stream Vegetated Buffers Needed to Protect Wildlife and Wildlife Habitat

PART Three of a Series entitled:
The Need for Stream Vegetated Buffers:
What Does the Science Say?

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Introduction

Riparian areas and wetlands make up approximately 4% of the Montana's landscape—yet about one-third of our wildlife species depend upon these areas for some part of their life cycle (Montana's Comprehensive Fish and Wildlife Conservation Strategy [MCFWCS], 2005). Unplanned commercial and residential development can cause significant, permanent loss and degradation of this critical wildlife habitat. One of the most effective tools available to local governments interested in minimizing habitat loss and degradation is to set back structures and protect streamside buffers with native vegetation (hereafter referred to as "building setbacks with vegetated buffers"). In order to use this tool, however, decision makers and citizens alike must understand the science behind different buffer widths.

Protecting wildlife is one of the important functions of building setbacks with vegetated buffers. This report—which is focused on wildlife and wildlife habitat—is part of a series of reports that summarizes the science behind buffers. Because it is the vegetative buffer portion of the tool that provides wildlife with critical habitat, scientific studies examining this issue focus on the portion of this tool with native vegetation. For more information on how building setbacks relate to vegetated buffers, see page 3.

This series of reports on the science behind vegetated buffers includes two other reports on other key elements of stream protection: water quality and fisheries:

- *Part I: Scientific Recommendations on the Size of Stream Vegetated Buffers Needed to Protect Water Quality*; and
- *Part II: Scientific Recommendations on the Size of Stream Vegetated Buffers Needed to Protect Fish and Aquatic Habitat.*

Local Governments and Wildlife

Local governments have the authority to protect wildlife and wildlife habitat under growth policies, subdivision regulations, and other land use planning statutes.

Each of these reports is designed to explain the science behind one of the many functions provided by vegetated buffers found along streams. Other topics for this series are currently being considered because building setbacks and vegetated buffers should also consider floodplains and seasonal water levels, stream migration corridors, density of development adjacent to the riparian corridor, and other factors.

Building Setbacks and Vegetated Buffers

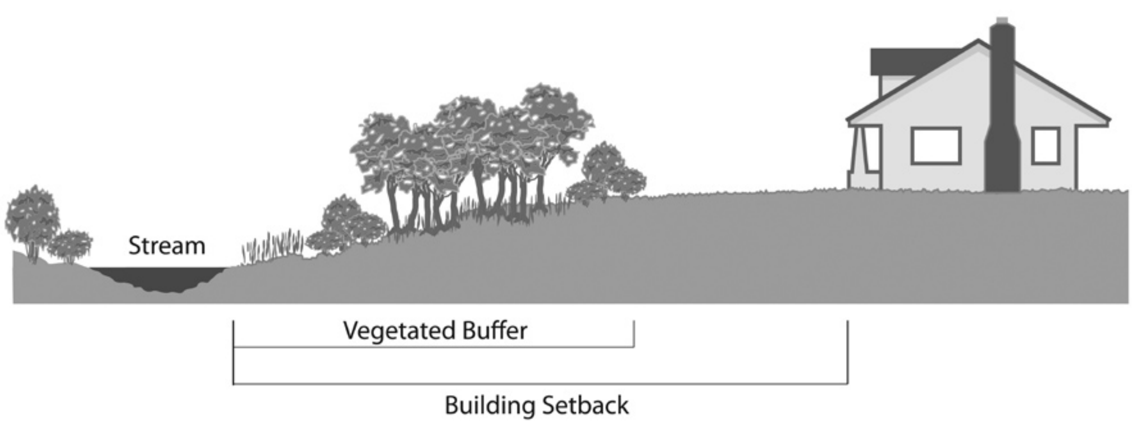
In order to understand setbacks and buffers, it is important to understand the following concepts:

Building setbacks or "no build areas" are the distance from a stream's ordinary high water mark to the area where new structures and other developments (such as highly polluting land uses—including roads, parking lots, and waste sites) are allowed.

Vegetated Buffers are not an additional area, but rather the portion of the building setback that is designated to remain undisturbed. These buffers are areas where all native vegetation, rocks, soil, and topography are maintained in their natural state or enhanced by additional planting of native plants. Lawns should not be considered part of the vegetated buffer. With their shallow roots, lawns are not particularly effective at absorbing and retaining water, especially during heavy rains. Consequently, they do not significantly filter out water pollutants. They can also be a major source of fertilizers and pesticides—substances that should be prevented from entering our streams and rivers.

How much space should be placed between a building and a vegetated buffer? The building setback should be wide enough to prevent degradation of the vegetated buffer. As an example, most families use the area between their home and the vegetated buffer for lawns, play areas, swing sets, picnic tables, vegetable gardens, landscaping, etc. As a result, the building setback should extend at least 25–50 feet beyond the vegetated buffer (Wenger 1999). A smaller distance between a building and a vegetated buffer, such as 10 feet, will most likely guarantee degradation of the vegetated buffer. A larger distance between structures and a vegetated buffer is recommended if the:

- River has a history of meandering; the setbacks should ensure that people and homes will not unwittingly be placed too close to the river's edge, in harm's way.
- Vegetated buffer is narrower than scientific studies recommend; a larger building setback can help protect water quality, fisheries, and aquatic habitat.
- Land is sloped and runoff is directed toward the stream (the steeper the slope, the wider a buffer or setback should be).
- Land use is intensive (crops, construction, development).
- Soils are erodible.
- Land drains a large area.
- Aesthetic or economic values need to be preserved.
- Wildlife habitat needs to be protected.
- Landowners desire more privacy.



Vegetated Buffers, Wildlife, and Wildlife Habitat

Perhaps the best-known reason for protection of streamside areas is their importance for wildlife and wildlife habitat. Over half of Montana's wildlife species are known to use or frequent riparian areas or wetlands. And at least 196 of our state's wildlife—approximately one-third of our wildlife species—are considered "riparian/wetland obligates," which means they *depend* upon these areas for some part of their life cycle (MCFWCS, 2005).

Riparian areas make up approximately 3% of the state's landscape; wetlands make up almost 1% of the state. Together, this small piece of Montana supports the habitat required to sustain an incredible number of species, including:

Amphibians and Reptiles. Streamside buffers and wetlands provide essential breeding, foraging, and over-wintering habitat for Montana's 16 native amphibians (salamanders, frogs, and toads), 3 turtles, and at least 7 of Montana's snakes (MCFWCS, 2005). Because many of these species (especially amphibians and turtles) are not very mobile, all of their habitat requirements need to be found in a relatively confined area. Streamside habitats provide drinking water; abundant food, such as aquatic plants, invertebrates (e.g. insects, spiders, snails, and worms), and small fish; dense vegetation and woody debris for cover; reproductive sites, which may necessitate having habitat for aquatic larvae; and a moist microclimate and a well-developed litter layer that provides numerous benefits, including protection during hot, dry summers.

Birds. Montana's riparian areas and wetlands provide breeding and nesting areas for at least 52% of Montana's breeding bird species (134 of Montana's 259 breeding birds) (Montana Audubon, unpublished data, 2006). Birds are diverse in their food and habitat needs—and streams and their associated vegetation provide essential requirements in a small area. As an example, riparian areas provide habitat for birds that primarily eat: flying insects (e.g. flycatchers, kingbirds, swallows, wrens); bark-dwelling insects (e.g. woodpeckers, chickadees, creepers); insects living on plants (e.g. vireos, orioles, thrush, and warblers are called gleaners), ground-dwelling insects and other invertebrates (e.g. towhees, sparrows); aquatic insects and/or aquatic plants (e.g. ducks, American Dipper); fish (e.g. Osprey, eagles, Belted Kingfishers, herons, mergansers); small birds and mammals (hawks and owls); and plant seeds, fruits, berries, buds, etc. (e.g. Ruffed Grouse, sparrows, waxwings). These birds nest on the ground (e.g. Ruffed Grouse, shorebirds, most ducks); in dense shrubs and willows (e.g. cuckoos, Rufous Hummingbirds, flycatchers, vireos, thrush, warblers, sparrows); in tree cavities (e.g. woodpeckers, smaller owls, cavity-nesting ducks, nuthatches, some wrens and swallows); in large trees, including snags (e.g. eagles, Osprey, hawks, larger owls, herons, flycatchers, vireos, orioles, warblers); and in tunnels dug into eroding banks (e.g. Bank Swallows, Belted Kingfishers). In addition to providing habitat for resident birds, Montana's stream and river corridors also provide essential food and resting areas for numerous and diverse migrating birds.

Mammals. Riparian areas provide important seasonal or year-round habitat for at least 56 of Montana's mammals, including 36 species of small mammals (rodents, rabbits, and shrews), 8 bats, 7 carnivores (otter, weasels, raccoons, and skunks), and 4 ungulates (white-tailed and mule deer, moose, and pronghorn) (MCFWCS, 2005). Mammals use streamside habitat for food, cover, protected access to water, travel routes, and relief from hot dry summers and cold, snowy winters. Small mammals use streamside areas for many of the reasons described under amphibians and reptiles above. Montana's bat species eat flying insects, which are abundant near streams; they also roost in these areas because of the availability of cavities, crevices, and/or foliage. Carnivores benefit from the diverse wildlife found in vegetative buffers (providing plentiful food sources), as well as from specific habitat components, such as hollow trees, snags, and debris piles for resting and denning sites (used by otter, bobcat, mink, marten, and many small mammals). Moose are the ungulate species most associated with streams and wetlands because of their dependence on riparian vegetation as food.

For the purpose of this publication, "wildlife" means terrestrial vertebrates: amphibians, reptiles, birds, and mammals. Table II lists the streamside buffer requirements for various species of Montana wildlife. Appendix I summarizes individual scientific studies about the buffer requirements for specific species, groups of species (amphibians, reptiles, etc.), different types of habitats (e.g. cottonwood forests, shrub-steppe, forests), and specific issues related to wildlife use of stream vegetated buffers (e.g. travel corridor use, wildlife response to disturbance, nest predation/parasitism).

Specific Habitat Components of Wildlife

As mentioned above, streamside buffers must provide enough room for wildlife to take shelter, find food, successfully raise young, and hide from and avoid predators. As more and more people choose to build homes or otherwise utilize the land next to Montana's streams and rivers, the pressures to develop these areas are increasing—often to the detriment of Montana's wildlife. Specific ways that streamside buildings and their associated development can impact wildlife habitat are described below:

Dense Cover and Woody Debris. Many wildlife species depend on dense cover to nest in, raise young, and hide or escape from predators. Removing riparian vegetation, including mowing or manicuring the landscape, removes an important habitat component for certain species. Snags and large, down logs also provide nesting and denning sites, places to rear young, and other significant habitat for amphibians, reptiles, some birds, and many small mammals.

Habitat Fragmentation. Land development commonly leads to habitat fragmentation. Building homes, roads, and associated development in riparian corridors creates a patchwork of habitat fragments, many of which are isolated from one another. The size of the remaining habitat patches significantly influences the diversity of wildlife species in an affected area. This is caused in part because wildlife species respond differently to human disturbance and development: those that do not adapt well to disturbance, avoid developed areas; those that become habituated or attracted to these areas, thrive. As an example, American Robin, European Starling, raccoons, and deer tend to thrive in fragmented habitat. Small, isolated patches of habitat can also be important to migrating birds when they are looking for short-term places to find food and shelter. Species that do not adapt well to habitat fragmentation are often rare or habitat specialists, including ground-feeding and ground-nesting birds, herons, eagles, Osprey, Pileated Woodpeckers, and many songbirds (flycatchers, vireos, American Redstart and other warblers, Spotted Towhee, and more). Additionally, less mobile wildlife, as a group, (amphibians, reptiles, and some small mammals) do not adapt well to habitat fragmentation because even small areas of unsuitable habitat (e.g. roads and parking lots) are difficult—and oftentimes impossible—to cross.

Narrow riparian strips are also known to attract a disproportionate number of predators, including predatory mammals (e.g. domestic cats, raccoons, skunks), egg-eating birds (e.g. crows, magpies), and nest parasitizers (Brown-headed Cowbirds). Brown-headed Cowbirds, found in mid to low elevations throughout Montana, feed in open areas and are often associated with livestock (horses or cattle) and houses with bird feeders. Cowbirds never build their own nests. Instead, they parasitize the nests of other birds by laying their eggs in other birds' nests. The host birds may abandon the nest, or raise the young cowbirds, usually raising fewer or none of their own young. In the West, cowbirds strongly prefer riparian deciduous forests near agricultural or residential areas; large, intact forests have significantly lower rates of parasitism than fragmented forests.

While narrow buffers offer habitat benefits to many species, most wildlife—especially birds and larger mammals—depend upon riparian areas that are much wider (see *Table II* and *Appendix I*).

> Local governments interested in determining the wildlife species using riparian areas in their jurisdiction should contact their local office of Montana Fish, Wildlife & Parks and the Montana Natural Heritage Program located in Helena (406-444-5354 or http://nhp.nris.mt.gov/).

Habitat Complexity. The more complex the vegetation, in both species of plants and diverse heights, the larger the variety of wildlife found. As an example, a healthy cottonwood forest, with 60-foot and taller trees in the canopy, can have pine, dogwood, green-ash, and box elder in the mid-story layer, and a variety of shrubs, grasses, and other plants closer to the ground. This diverse riparian habitat has the "greatest concentration of plants and animals in Montana" (MCFWCS, 2005). Although riparian areas can also be naturally dominated by pine trees, shrubs, grasslands, and other vegetation, these other habitat types support different and fewer species of wildlife than cottonwood gallery forests. One reason why many biologists are concerned about the spread of Russian olive in eastern Montana is that this plant species is shade-tolerant and will slowly out-compete and replace cottonwoods, green ash, and other native species over time. A Russian olive monoculture does not benefit as many wildlife species as a healthy, diverse native cottonwood forest.

About This Report—Methods Used

This report summarizes the recommendations of 83 scientific studies that tested how various stream vegetated buffers protect wildlife and wildlife habitat (see *Appendix I*). These scientific studies were reviewed by the authors of 4 review publications; two additional sources provided supplemental information on Montana-specific wildlife species. Please note that the information in this report was taken from the text and tables of these 6 publications—and that in most cases the original studies were not reviewed in this report.

The 4 review publications are:

Fischer, R.A. 2000. Width of riparian zones for birds. EMRRP Technical Notes Collection (TN EMRRP-SI-09), U.S. Army Corps of Engineer Research and Development Center, Vicksburg, MS. 7 pp.

Fischer, R.A. C.O. Martin, and J.C. Fischenich. 2000. Improving riparian buffer strips and corridors for water quality and wildlife. International Conference on Riparian Ecology and management in Multi-Land Use Watersheds. American Water Resources Association. August 2000. 7 pp.

Knutson, K.L., and V.L. Naef. 1997. Management recommendations for Washington's priority habitats: riparian. Wash. Dept. Fish and Wildlife, Olympia, WA. 181 pp.

Wenger, S.J. 1999. A review of the scientific literature

on riparian buffer width, extent and vegetation. Athens: Institute of Ecology Office for Public Service and Outreach, University of Georgia. 59pp.

Information from two additional publications is also included in this report:

Ellis, Janet, and Jim Richard. 2008. A Planning Guide for Protecting Montana's Wetlands and Riparian Areas. Revised edition. Bozeman, MT, Montana Watercourse, publication MTW-01-03. 105 pp.

This publication is included because it contains information on stream vegetated buffer requirements of several Montana wildlife species that were not found in the above review publications (e.g. otter, bobcat, and cavity nesting ducks).

Schwab, Nathan A. 2006. Roost-site selection and potential prey sources after wildland fire for two insectivorous bat species (*Myotis evotis* and *Myotis lucifugus*) in mid-elevation forests of western Montana. 89 pp.

This publication is included because it contains original scientific research on stream vegetated buffer requirements of two Montana bats with fairly wide distribution. No information on bats appeared in the above review publications.

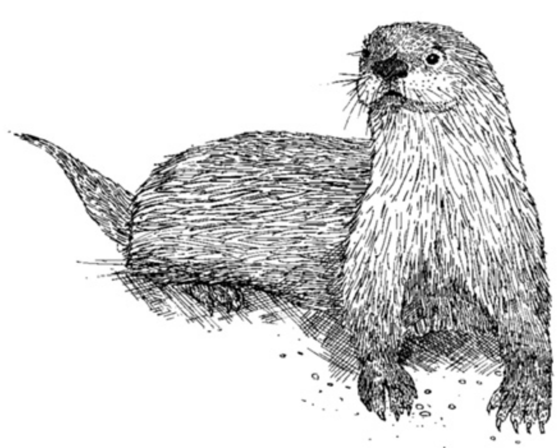
Appendix II contains the original references cited in the 6 publications described above, allowing individuals using Appendix I to see the full title of all original references, as well as have sufficient information to access all references, if necessary.

Summary of Recommendations of Scientific Studies

The future of Montana's wildlife depends on the thoughtful planning and protection of vegetated buffers along our streams. Streamside areas only represent a small part of our state—less than 4%. Yet more than half of our state's wildlife use these areas for food; protected access to water; cover; resting areas during migration; travel routes; relief from hot dry summers or cold, snowy winters; and breeding areas. Consequently,:

Scientific studies recommend that, in order to protect wildlife and wildlife habitat, 300-foot (100-meter) stream vegetated buffers be maintained. Certain wildlife species need a larger vegetated buffer.

This recommendation is drawn from the conclusions of 6 publications that reviewed a total of 83 separate scientific studies on wildlife, wildlife habitat, and stream vegetated buffers. Specific conclusions



and recommendations by the authors in these review articles are quoted in Table I.

In order to better understand the conclusions found above, Table II summarizes the scientific information for various wildlife species and groups of species found in Montana. Additionally, Appendix I contains study-specific information for all 83 scientific studies reviewed in the 6 publications featured in this report. It should be noted that many of these studies found in Appendix I underwent extensive peer review before they were published in a professional journal or report of a scientific government agency. Because the habitat needs of different wildlife are so diverse, the summarized studies show a range of buffer widths. It would be very costly to duplicate these studies on a case-by-case basis; hence the recommendations given here are intended to be protective in most situations, based on the findings of a wide range of studies. If localized information on area conditions is available (vegetation maps, floodplain maps, etc.), this information can also be used to ensure that buffers more accurately fit local conditions.

Table I. A summary of the specific conclusions and recommendations of six publications on the size of vegetated buffers needed for wildlife and wildlife habitat protection. All authors emphasized that different species of wildlife require different vegetated buffer widths.

Ellis and Richards 2008	"While narrow buffers offer habitat benefits to many species, most wildlife—especially birds and larger mammals—depend upon riparian areas that are a minimum of 300 feet wide."
Fischer 2000	"If avian habitat is a management objective, managers should consider managing for riparian zones that are at least 100 m [328 feet] wide."
Fischer et al 2000	"Recommended widths for ecological concerns in buffer strips typically are much wider than those recommended for water quality concerns, often exceeding 100 m [328 feet] in width. These recommendations usually apply to either side of the channel in larger river systems and to total width along smaller streams where the canopy is continuous across the channel."
	"Management for long, continuous buffer strips rather than fragments of greater width should also be an important consideration."
Knutson and Naef 1997	The mean width of all wildlife studies reviewed indicate that 88 meters (287 feet) is required to protect wildlife habitat.
Schwab 2002	"Our research shows the average minimum distance between [bat] roost sites and perennial water to be 90 meters [295 feet]."
Wenger 1999	"While narrow buffers offer considerable habitat benefits to many species, protecting diverse terrestrial riparian wildlife communities requires some buffers of at least 100 m (~300 ft)."
	"[H]owever, 300 ft wide buffers are not practical on all streams in most areas. Therefore, minimum riparian buffer width should be based on water quality and aquatic habitat functions. . . . In addition, at least a few wide (300–1000 ft/~90–300 m) riparian corridors and large blocks of upland forest should be identified and targeted for preservation."

Table II. Summary of stream vegetated buffer widths needed by various Montana wildlife. Research shows that the following buffer widths are needed to support different species of Montana wildlife. This table was compiled using information from the scientific studies reported in Appendix I from the 6 publications featured in this report.

Wildlife dependent on wetlands or watercourses	Desired Buffer Width in feet
Elk caving grounds, Sandhill Crane nests	1000 +
Great Blue Heron nest	820–985
Cavity nesting ducks	600
Bald Eagle nests	400–1,320
Pileated Woodpecker, fisher, mink	330–600
Large mammals, bobcat, red fox, otter, muskrat, dabbling ducks	330
Wood Duck	250–600
Osprey, pine marten	200–330
Spruce Grouse	200
Amphibians and reptiles, Belted Kingfisher, beaver	100–330
Small mammals	40–300
Hairy Woodpecker	130
Deer, Ring-necked Pheasant	75
Mourning Dove, Downy Woodpecker	50
Songbirds	**50–660**
American Redstart, Spotted Towhee	660
Warbling Vireo	300
Brown Creeper, Ruby-crowned Kinglet, Swainson's Thrush	200
Red-eyed Vireo, Brown Thrasher	130
Black-capped Chickadee, White-breasted Nuthatch	50

Appendix I.

Summary of 83 Scientific Studies Conducted on the Size of Stream Vegetated Buffers Needed to Protect Wildlife and Wildlife Habitat. The information in this table was taken from the text and tables of the 6 publications described above. This table summarizes (1) the purpose of the buffer that was tested in a scientific study (Vegetated Buffer Function); (2) the size (in meters and feet) of the vegetated buffer tested; (3) the author of the scientific study who tested the buffer's function and size; and (4) the name of the publication where the scientific study was summarized. As much as possible, the studies in this table are listed from most protective to least protective. Note that information about fish and instream habitat appears in Part II of this report series, *Scientific Recommendations on the Size of Stream Vegetated Buffer Needed to Protect Fish and Aquatic Habitat*.

GENERAL WILDLIFE HABITAT				
Vegetated Buffer Function	**Distance from stream in meters**	**Distance from stream in feet**	**Author of Original Scientific Study**	**Name of Review Article**
General wildlife habitat	100-year floodplain plus additional upland area on at least one side	100-year floodplain plus additional upland area on at least one side	Schaefer and Brown 1992	Wenger 1999
General wildlife habitat—flooding needed to regenerate cottonwood forests in western United States (dam-altered flows cause problems)	100-year flood-plain	100-year flood-plain	Poff et al 1977	Wenger 1999
General wildlife habitat	61	200	Zeigler 1992	Knutson and Naef 1997
Riparian vegetation width in shrub-steppe	50–100	164–328	Medin and Clary 1991	Knutson and Naef 1997
General wildlife habitat—maintain plant diversity	≥30	≥100	Spackman and Hughes 1995	Fischer et al 2000
General wildlife habitat—depends on species	9–201	30–660	Johnson and Ryba 1992	Knutson and Naef 1997; Castelle et al 1994
Width of riparian vegetation—depends on species	20–50	66–164	Strong and Bock 1990	Knutson and Naef 1997

REPTILES AND AMPHIBIANS				
	Meters	**Feet**	**Author of Original Scientific Study**	**Name of Review Article**
Reptiles and amphibian habitat	≥165	≥540	Semlitsch 1998	Fischer et al 2000
Reptile and amphibian habitat	≥135	≥443	Buhlmann 1998	Fischer et al 2000
Reptiles and amphibian habitat	100	328	Burbrink et al 1998	Wenger 1999; Fischer et al 2000
Reptiles and amphibian habitat —buffer requirements for riparian-dependent species	75–100	246–328	Gomez and Anthony 1996	Wenger 1999
Reptiles and amphibian habitat—riparian-dependent species more numerous with buffer width in mature vegetation	30–95	100–312	Rudolph and Dickson 1990	Knutson and Naef 1997
Reptiles and amphibian habitat—Full complement of reptiles and amphibians	≥30	≥100	Rudolph and Dickson 1990	Knutson and Naef 1997; Fischer et al 2000
Reptile habitat—requirements for certain fresh water turtles	275	902	Burke and Gibbons 1995	Wenger 1999

REPTILES AND AMPHIBIANS (continued)				
	Meters	Feet	Author of Original Scientific Study	Name of Review Article
Amphibian habitat—Distance needed for sediment control, important to maintaining habitat quality for Cascade torrent, Columbia torrent, Dunn's, and Van Dyke's salamanders	31–88	100–289	Erman et al 1977, Lynch et al 1985, Terrell and Perfetti 1989, Johnson and Ryba 1992	Knutson and Naef 1997; Fischer et al 2000
Amphibian habitat—Distance needed for woody debris recruitment, an important habitat component for Cascade torrent, Columbia torrent, Dunn's, and Van Dyke's salamanders	31–55	100–180	Bottom et al 1983, Harmon et al 1986, Murphy and Koski 1989, McDade et al 1990, Van Sickle and Gregory 1990	Knutson and Naef 1997

BIRDS				
	Meters	Feet	Author of Original Scientific Study	Name of Review Article
General Bird Habitat				
Bird habitat—size of naturally vegetated buffer needed to retain full complement of birds	125	410	Croonquist and Brooks 1993	Knutson and Naef 1997
Bird habitat—Full compliment of birds present; avian richness declines after this point in cottonwood floodplains	127	417	Sedgewick and Knopf 1986	Knutson and Naef 1997
Bird habitat—riparian buffer size needed to include 90% of bird species along mid-order streams	150–175	492–574	Spackman and Hughes 1995	Wenger 1999; Fischer 2000; Fischer et al 2000
Bird habitat—Riparian buffers should be at least this wide to provide some nesting habitat for sensitive species	100	328	Keller et al 1993	Fischer 2000
Bird habitat—recommended buffer for birds	75–200	246–656	Jones et al 1988	Knutson and Naef 1997
Bird habitat—minimum buffer width recommended for bird species	70	230	Kinley and Newhouse 1997	Wenger 1999
Bird habitat—bottomland hardwood strips can support diverse bird populations; at least 500 m needed to maintain complete avian community	50–500	164–1640	Kilgo et al 1998	Wenger 1999; Fischer 2000; Fischer et al 2000
Bird habitat—buffer distance needed to provide sufficient breeding habitat for area-sensitive forest birds.	≥100	≥328	Mitchell 1996	Fischer 2000; Fischer et al 2000
Bird habitat—45% reduction in birds in agricultural areas if no fencerows are within this distance of a stream	100	328	Croonquist and Brooks 1993	Knutson and Naef 1997
Bird habitat—bird species sensitive to disturbance did not occur unless an undisturbed corridor this wide was present	25	82	Croonquist and Brooks 1993	Knutson and Naef 1997

	Meters	Feet	Author of Original Scientific Study	Name of Review Article
General Bird Habitat (continued)				
Bird habitat—depends on species	50–1,600	164–5,250	Richardson and Miller 1997	Fischer et al 2000
Bird forest habitat—minimum riparian width to sustain forest-dwelling birds	≥60	≥200	Darveau et al 1995	Knutson and Naef 1997; Fischer 2000; Fischer et al 2000
Bird forest habitat—riparian buffers along headwater streams provide the most benefit for forest-associated bird species if they are >40 m	>40	>131	Hagar 1999	Fischer 2000; Fischer et al 2000
Bird habitat—Narrow stream corridors (15–50 m) can help maintain bird diversity even though they are insufficient for protecting forest-dependent species	15–50	50–164	Thurmond et al 1995	Wenger 1999
Bird forest habitat—small buffers will benefit some edge-dwelling songbirds	15–23	49–76	Triquet et al 1990	Wenger 1999
Birds-Nest Predation				
Nest predation—Brown-headed Cowbird—distance cowbirds penetrate from stream opening	240	787	Gates and Giffin 1991	Knutson and Naef 1997
Nest predation—riparian buffers this wide reduce edge-related nest predation.	≥150	≥490	Vander Haegen and deGraaf 1996	Fischer et al 2000
Nest predation—riparian buffer width that reduces nest predation	100	328	Temple 1986	Knutson and Naef 1997
Waterfowl				
Wood Duck—maximum distance from water where Wood Ducks will nest	350	1148	Gilmer et al 1978	Knutson and Naef 1997
Wood Duck—nest within this distance	200	656	Lowney and Hill 1989	Knutson and Naef 1997
Wood Duck—nesting distance	183	600	Grice and Rogers 1965	Knutson and Naef 1997
Wood Duck—nesting where woody/herbaceous cover is between 50-75%	183	600	Sousa and Farmer 1983	Knutson and Naef 1997
Wood Duck—average distance of wood duck nests from water	80	262	Gilmer et al 1978	Knutson and Naef 1997
Lesser Scaup prefer nesting habitat within this distance in emergent vegetation	50	164	Allen 1986a	Knutson and Naef 1997
Harlequin—stream buffer needed to maintain harlequin nests	50	164	Cassirer and Groves 1990	Knutson and Naef 1997
Harlequin—large woody debris use by loafing Harlequin Ducks	30+	100+	Murphy and Koski 1989	Knutson and Naef 1997
Cavity nesting ducks (includes Wood Ducks, goldeneye, Buffelhead, and Hooded Merganser)	182	600	Cohen 1997	Ellis and Richard 2008

	Meters	Feet	Author of Original Scientific Study	Name of Review Article
Birds—Species Information (Birds generally listed in taxonomic order)				
Waterfowl				
Dabbling ducks (includes Pintail, teal, widgeon, Mallards, shoveler, etc.)	100	330	Cohen 1997	Ellis and Richard 2008
Grouse and their Allies				
Ring-necked Pheasant—buffer size needed in Eastern Washington	23	75	Mudd 1975	Knutson and Naef 1997
Spruce Grouse—minimum buffer width to sustain	60	197	Darveau et al 1995	Knutson and Naef 1997
Herons and Cranes				
Great Blue Heron—minimum buffer zone around peripheries of Great Blue Heron colonies	250–300	820–984	Bowman and Siderius 1984, Kelsall 1989, Vos et al 1985	Knutson and Naef 1997
Great Blue Heron—nesting	250–300	820–984	Parker 1980, Short and Cooper 1985, Vos et al 1985	Knutson and Naef 1997
Great Blue Heron—recommended disturbance-free zone around heron nesting areas	250	820	Short and Cooper 1985	Knutson and Naef 1997
Great Blue Heron—nesting	250	820	Short and Cooper 1985	Knutson and Naef 1997
Great Blue Heron—recommended disturbance-free zone around heron feeding areas	100	328	Short and Cooper 1985	Knutson and Naef 1997
Sandhill Cranes—recommended disturbance-free zone around Sandhill Crane nesting areas	400	1,312	Schlorff et al 1983	Knutson and Naef 1997
Raptors				
Osprey nesting—recommended hiking trail buffer near Osprey nests	91	300	Zarn 1994	Knutson and Naef 1997
Osprey nesting—no cut zone	61	200	Zarn 1974, Westall 1986	Knutson and Naef 1997
Bald Eagle—distance from human activity at which nesting eagles are disturbed	400	1,320	Montana Bald Eagle Working Group 1991	Ellis and Richard 2008
Bald Eagle—recommended buffer for eagle perch areas with little screening	250–300	820–984	Stalmaster 1980	Knutson and Naef 1997
Bald Eagle—distance from human activity at which feeding eagles are disturbed	200	656	Skagen 1980	Knutson and Naef 1997
Bald Eagle—average distance of successful Bald Eagle nests from human disturbance	119	396	Grubb 1980	Knutson and Naef 1997
Bald Eagle—eagles nest within this distance of water	100	328	Small 1982	Knutson and Naef 1997

	Meters	Feet	Author of Original Scientific Study	Name of Review Article
Raptors (continued)				
Bald Eagle—recommended leave strip for Bald Eagles along shoreline of major feeding areas	75–100	246–328	Stalmaster 1980	Knutson and Naef 1997
Bald Eagle—most Bald Eagles perch within this distance of water during daylight hours	50	164	Stalmaster 1980	Knutson and Naef 1997
Doves, Cuckoos, and Kingfishers				
Mourning Dove	15	50	Mudd 1975	Knutson and Naef 1997
Belted Kingfisher roosts	30–60	100–197	Prose 1985	Knutson and Naef 1997
Yellow-billed Cuckoo—100 meter minimum riparian buffer width for breeding habitat; stream length must be at least 300 meters	≥100	≥328	Gaines 1974	Knutson and Naef 1997; Fischer 2000
Yellow-billed Cuckoo—buffer required by cuckoo	91	300	Gaines and Laymon 1984	Knutson and Naef 1997
Woodpeckers				
Downy Woodpecker	25	82	Stauffer and Best 1980	Knutson and Naef 1997
Downy Woodpecker	15	50	Cross 1985	Knutson and Naef 1997
Hairy Woodpecker—minimum mean width supporting breeding populations of Hairy Woodpeckers	40	133	Stauffer and Best 1980	Knutson and Naef 1997
Northern Flicker avoided isolated forest patches farther than this distance from water	124	407	Gutzwiler and Anderson 1987	Knutson and Naef 1997
Pileated Woodpecker—nesting	150–183	492–600	Conner et al 1975, Schroeder 1983	Knutson and Naef 1997
Pileated Woodpecker—most Pileated Woodpeckers nest within this distance of water	150	492	Conner et al 1975, Schroeder 1983	Knutson and Naef 1997
Pileated Woodpecker—nesting within this distance of stream	100	328	Small 1982	Knutson and Naef 1997
Pileated Woodpecker do not use buffers this size	15–23	50–75	Triquet et al 1990	Knutson and Naef 1997
Songbirds (Songbirds that are "Neotropical Migrants" breed in Montana but winter in the neotropics (Central and South America))				
Neotropical Migrants were more abundant in riparian corridors wider than 100 meters	≥100	≥328	Triquet et al 1990	Knutson and Naef 1997; Fischer 2000; Fischer et al 2000
Neotropical Migrants—distance needed to maintain functional assemblages of 6 common neotropical migratory birds	≥100	≥328	Hodges and Krementz 1996	Knutson and Naef 1997; Wenger 1999; Fischer 2000; Fischer et al 2000

	Meters	Feet	Author of Original Scientific Study	Name of Review Article
Songbirds (continued)				
Neotropical Migrants—minimum buffer width needed to support area-sensitive neotropical migrant birds in forest/agricultural areas	100	328	Keller et al 1993	Knutson and Naef 1997; Wenger 1999; Fischer et al 2000
Neotropical Migrants—sensitive species of flycatchers and warblers inhabit buffers of this size	75–150	246–492	Smith and Schaefer 1992	Wenger 1999
Neotropical Migrants—minimum riparian width to sustain neotropical migrants (many neotropical birds will not inhabit narrower buffers)	≥50	164	Tassone 1981	Knutson and Naef 1997; Fischer 2000
Neotropical Migrants—significant increases in bird densities found for several species	50–100	164–328	Hodges and Krementz 1996	Wenger 1999
Neotropical Migrants—narrow buffer supports more songbirds than no buffer near agricultural fields	50	164	Keller et al 1993	Wenger 1999
Neotropical Migrants—sensitive species of flycatchers and warblers *missing* from buffers of this size	20–60	66–197	Smith and Schaefer 1992	Wenger 1999
Neotropical Migrants do not use buffers this size	15–23	50–75	Triquet et al 1990	Knutson and Naef 1997
Warbling Vireo—average distance of warbling vireo nests from water	90	295	Gilmer et al 1978	Knutson and Naef 1997
Red-eyed Vireo—minimum mean width supporting breeding populations of red-eyed vireos	40	133	Stauffer and Best 1980	Knutson and Naef 1997
Black-capped Chickadee	15	50	Cross 1985	Knutson and Naef 1997
White-breasted Nuthatch	17	57	Stauffer and Best 1980	Knutson and Naef 1997
Brown Creeper—minimum buffer width to sustain	60	197	Darveau et al 1995	Knutson and Naef 1997
Ruby-crowned Kinglet—minimum buffer width to sustain	60	197	Darveau et al 1995	Knutson and Naef 1997
Swainson's Thrush—minimum buffer width to sustain	60	197	Darveau et al 1995	Knutson and Naef 1997
Brown Thrasher	100	330	Cohen 1997	Ellis and Richard 2008
American Redstart—minimum mean width to support breeding populations of American Redstarts	200	656	Stauffer and Best 1980	Knutson and Naef 1997
Spotted Towhee—minimum mean width to support breeding populations of Spotted Towhees	200	656	Stauffer and Best 1980	Knutson and Naef 1997
Red-winged Blackbird—foraging distance from nests in wetlands	200	656	Short 1985	Knutson and Naef 1997

MAMMALS				
	Meters	Feet	Author of Original Scientific Study	Name of Review Article
General Habitat for Mammals				
Mammal habitat	≥50	≥164	Dickson 1989	Fisher et al 2000
Large mammals—recommended riparian buffer for large mammals	100	328	Jones et al 1988	Knutson and Naef 1997
Small mammals—recommended riparian buffer width for small mammals	67–93	220–305	Jones et al 1988	Knutson and Naef 1997
Small mammals—diversity and species composition similar to undisturbed sites	67	220	Cross 1985	Wenger 1999
Small mammals—no small mammal species lost	12–70	39–230	Cross 1985	Knutson and Naef 1997
Mammal—Species Information				
Dusky shrew—food and cover	183	600	Clothier 1955	Knutson and Naef 1997
Bats—average minimum distance between roost sites and streams for two Montana bat species	90	295		Schwab 2002
Beaver—majority of foraging	100	328	Allen 1983	Knutson and Naef 1997
Beaver foraging: 30 meters = 90% foraging distance for beaver; 100 meters = maximum foraging distance (but 200 meters has been reported)	30–100	100–328	Allen 1983, Hall 1970	Knutson and Naef 1997
Muskrat	100	330	Cohen 1997	Ellis and Richard 2008
Carnivores				
Mink will not use areas farther than 200 meters from water	200	656	Melquist et al 1981	Knutson and Naef 1997
Mink—riparian buffer needed for dens, cover, and forage	100	328	Melquist et al 1981, Allen 1986b	Knutson and Naef 1997
Mink—buffer area of optimum cover and forage habitat	100	328	Allen 1986b	Knutson and Naef 1997
Otter	100	330	Cohen 1997	Ellis and Richard 2008
Fisher travel corridor—needed on each side of stream to provide a 600 foot travel corridor in mature uncut basins for fisher	91	300	Freel 1991	Knutson and Naef 1997
Fisher use	100	328	Small 1982	Knutson and Naef 1997
Pine Marten—vegetation within this distance used by marten as travel corridor and habitat	100	328	Small 1982	Knutson and Naef 1997
Pine Marten—food and cover	61	200	Spencer 1981	Knutson and Naef 1997

	Meters	Feet	Author of Original Scientific Study	Name of Review Article
Carnivores (continued)				
Pine Marten—provides travel corridors for marten when buffers are on both sides of streams in mature uncut basins (total buffer is 91 meters)	46	151	Freel 1991	Knutson and Naef 1997
Bobcat	100	330	Cohen 1997	Ellis and Richard 2008
Red fox—Vegetation within this distance used by red fox as travel corridor and habitat	100	328	Small 1982	Knutson and Naef 1997
Elk and Deer				
Elk calving grounds are usually within this distance of water	305	1,000	Thomas 1979	Knutson and Naef 1997
Deer and elk cover—distance hiding cover needed at 90% vegetative cover	61	200	Mudd 1975	Knutson and Naef 1997
Deer—riparian buffer needed by deer in eastern Washington	23	75	Mudd 1975	Knutson and Naef 1997

Appendix II

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