Riparian Areas

Photo courtesy of WGFD

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Habitat Description

Riparian areas are lands immediately adjacent to creeks, streams, and rivers. They are the interface between aquatic ecosystems and terrestrial ecosystems. Functionally, they are bounded on their outer edge by the limits of flooding and at their upper edge by the extent of the canopy vegetation (Swanson et al. 1982). While riparian definitions can be extensive and complex (e.g., Karr and Schlosser 1978, Cowardin et al. 1979), the riparian area is simply the distinct ribbon of green demarcating streams from uplands across much of the West. They are vital zones of ecosystem processes that provide linkages across landscapes, supporting diverse plant and animal communities (Gregory et al. 1991). The importance of riparian habitat to wildlife far exceeds its abundance. Less than 2% of the surface area of Wyoming, Nevada, and Montana consists of wetland and riparian systems, yet a majority of species depend upon them (McKinstry et al. 2004).

The identification, classification, and management of riparian zones received increasing attention in the 1980s and 1990s, and numerous workshops, conferences, and symposia were devoted to the topic (e.g., Johnson et al. 1985). Federal agencies formed interdisciplinary work groups to develop consistent approaches for classifying riparian areas (Gebhardt et al. 1990). For example, the Ecological Site Inventory was developed to classify riparian areas (Leonard et al. 1992), and the practice of assessing Proper Functioning Condition (PFC) followed (Prichard et al. 1998). Today, an extensive body of literature describes the ecological functions and habitat values of riparian areas (Naiman et al. 2005).

A habitat map produced for the Wyoming Gap Analysis program indicates that riparian areas cover approximately 1.2% of Wyoming (Merrill et al. 1996). In this State Wildlife Action Plan (SWAP), the eight NatureServe Ecological Systems comprising the riparian habitat type are listed in Table 15 and are fully described online (http://www.natureserve.org/explorer) (NatureServe 2009). These are diverse systems represented by well over 100 different community associations. The riparian habitat type is a sub-component of the broader wetland habitat type (i.e., wet meadows, prairie potholes, bogs, seeps, flood-irrigated fields, and the vegetative shoreline of lakes and other types of open water). Wetlands and their associated species assemblages, threats, and conservation actions are covered in a separate habitat chapter of this SWAP and in Copeland et al. (2010).

The eight NatureServe (2009) riparian ecological systems in Wyoming can be broadly segregated into mountain and lowland habitats. Mountain riparian habitats vary considerably from those found in lowlands because of steeper stream gradients, cooler temperatures, and less soil deposition (Knight 1994), with the exception of mountain areas where the topography flattens into broad meadows. Mountain riparian vegetation is often characterized by sedges and short willow shrublands (Winward 2000). As elevation decreases, alder and tall willows become common, together with Engelmann spruce, narrowleaf cottonwood, lodgepole pine, and aspen, and occasionally blue spruce and balsam poplar (Knight 1994).

Lowland riparian areas in the West are often characterized by narrow bands of trees and shrubs surrounded by uplands of vegetation of lower stature (Knopf et al. 1988, Montgomery 1996). Historically, cottonwoods have been the dominant lowland riparian tree species (Braatne et al. 1996). For seedling establishment, cottonwoods must receive full sunlight and be free from competing vegetation (Rood and Mahoney 1990, Friedman et al. 1997). Such sites often occur along river and stream banks after high spring flows that deposit or expose alluvial soils (Friedman et al. 1997). Boxelder, lanceleaf cottonwood, peachwood willow, and occasionally American elm are also common riparian tree species, particularly in eastern Wyoming (Jones and Walford 1995). Understory shrubs include chokecherry, hawthorn, rubber rabbitbrush, silver buffalo berry, silver sagebrush, skunkbush sumac, wild rose, and various species of willow (Knight 1994).

Riparian areas provide critical ecological functions (Gregory et al. 1991, Annear et al. 2004). Healthy riparian areas buffer water loss from upland drainages and recharge aquifers. The dense, diverse, and complex vegetation of healthy riparian areas filter chemical and organic wastes, trap sediment, build and maintain stream banks, reduce soil erosion, and moderate stream temperatures. The vegetation offers high quality foraging and nesting habitat, creates movement corridors for wildlife, and provides niches to a multitude of species. Riparian plant communities provide direct and indirect organic inputs to support stream ecosystems (Vannote et al. 1980), and terrestrial invertebrate inputs are often a key component of stream food webs (Saunders and Fausch 2006). Woody debris contributions from riparian areas to streams can provide habitats for fish and invertebrates and influence stream channel stability and dynamics.

Riparian areas are among the habitat types most used and altered through human activity and development. Wildlife abundance, water availability, vegetation diversity, soil productivity, and an often gentle topography attracted both Native Americans and early Europeans settlers to riparian zones. Today, accordingly, a high percentage of riparian areas are privately owned. In addition, riparian areas are used for agriculture, recreation, travel, water development, and housing. Most communities in Wyoming occur in conjunction with riparian zones.

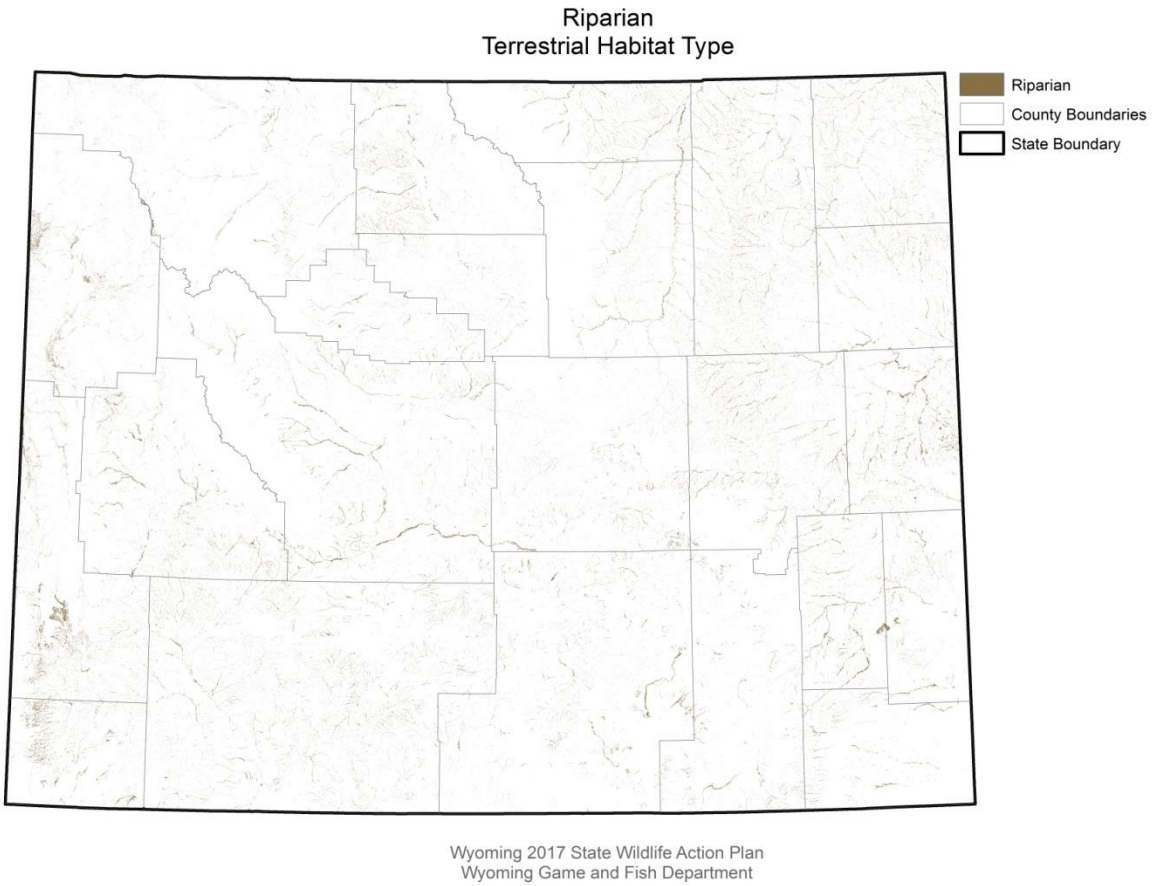


FIGURE 15. Wyoming Riparian Areas

TABLE 15. Wyoming Riparian NatureServe Ecological Systems[1]

1. Western Great Plains Floodplain
2. Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
3. Rocky Mountain Lower Montane Riparian Woodland and Shrubland
4. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland
5. Rocky Mountain Subalpine-Montane Riparian Woodland
6. Rocky Mountain Subalpine-Montane Riparian Shrubland
7. Northwestern Great Plains Riparian
8. Western Great Plains Riparian Woodland and Shrubland

[1] Descriptions of NatureServe Ecological Systems which make up this habitat type can be found at: NatureServe Explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

TABLE 16. Wyoming Riparian Species of Greatest Conservation Need

Mammals
Fringed Myotis
Hayden's Shrew
Little Brown Myotis
Long-eared Myotis
Long-legged Myotis
Meadow Jumping Mouse
Moose
Northern Long-eared Myotis
Pallid Bat
Preble's Meadow Jumping Mouse
Preble's Shrew
Pygmy Shrew
Northern River Otter
Spotted Bat
Townsend's Big-eared Bat
Water Vole
Western Spotted Skunk
Yuma Myotis

Birds
Bald Eagle
Black-billed Cuckoo
Black-chinned Hummingbird
Calliope Hummingbird
Ferruginous Hawk
Golden Eagle
Great Blue Heron
Harlequin Duck
Lewis's Woodpecker
MacGillivray's Warbler
Red-headed Woodpecker
Rufous Hummingbird
Swainson's Hawk
Trumpeter Swan
Willow Flycatcher
Yellow-billed Cuckoo

Reptiles
Eastern Spiny Softshell
Plains Gartersnake
Red-sided Gartersnake
Smooth Greensnake
Valley Gartersnake
Western Painted Turtle

Amphibians
Columbia Spotted Frog
Great Plains Toad
Northern Leopard Frog
Plains Spadefoot
Great Basin Spadefoot
Western Tiger Salamander
Western Toad
Wood Frog
Wyoming Toad

Riparian Area Wildlife

Riparian areas account for less than 1% of the western landscape, but have a disproportionately high value as wildlife habitat (Knopf et al. 1988, Montgomery 1996). Within Wyoming, 61% of 445 terrestrial vertebrate species are believed to show preference for riparian habitats (Olson and Gerhart 1982). This is especially true for birds. In Wyoming, approximately 73 avian species have been identified as using riparian habitats (Nicholoff 2003). Bird diversity in riparian habitats has been linked to the complex vertical structure of these habitats compared to adjacent grasslands or shrubland habitats (Slater 2006). Some riparian bird species, such as the yellow-billed cuckoo and willow flycatcher, are among the most imperiled migratory species in Wyoming (Nicholoff 2003).

Elk, moose, mule deer, white-tailed deer, pronghorn, and small mammals, as well as their predators, all have strong seasonal or year-long associations with riparian habitats (Buskirk 1991). Riparian corridors and the rivers they bound play an essential role in river otter distributions (Rudd et al. 1986). The value of riparian corridors increases for shrews and jumping mice with the presence of grassy vegetation (i.e., forage and cover) and prey (i.e., seeds and insects). Riparian areas provide crucial habitat for wildlife in the form of wildlife movement corridors and migration habitats. The forage, cover, and water of riparian areas allow birds and mammals to move across otherwise harsh prairies and desert landscapes. Bats, in particular, use riparian habitats for commuting, migrating, roosts, and foraging habitat.

Many species of birds are excellent indicators of the condition of riparian vegetation in Wyoming and the West. Some are considered riparian obligates because they build greater than 90% of

their nests in riparian vegetation or because 90% or more of their abundance occurs in riparian vegetation during the breeding season. Others are considered riparian dependent species either because 60–90% of their nests are built in riparian vegetation or because 60–90% of their abundance occurs in riparian habitat during the breeding season. All riparian species use one or more of the vegetation layers present in a healthy riparian system (i.e., understory, mid-story, and canopy).

Beaver are a fundamental factor influencing riparian landscapes. They create meadows and broaden the floodplain as they create dams. This increases sedimentation and encourages growth of riparian vegetation (Knight 1994). Beaver ponds provide important habitat for native fish species including Colorado River cutthroat trout, Yellowstone cutthroat trout, Bonneville cutthroat trout, and Snake River cutthroat trout. These ponds provide overwintering fish habitat, while supporting numerous aquatic mammals such as river otter, mink, and muskrat. Water held behind beaver dams and in surrounding banks enhances year-round stream flow and is especially important for helping maintain late season flows in many small streams. Bird densities among some beaver-influenced riparian areas have been found to be three times those of adjacent riparian habitats (Collins, 1993). Over the centuries, beaver ponds have trapped tens to hundreds of billions of cubic meters of sediment that would otherwise have been carried downstream (Naiman et al. 1988) so that today the physical character and vegetation of many meadowlands is the result of historic beaver activity.

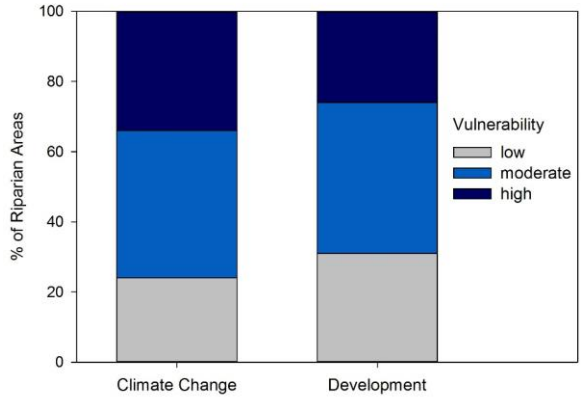
Riparian habitat is required by many Wyoming amphibian and reptile assemblages. Amphibians rely on aquatic habitat for a portion of their life, and frogs, toads, and salamanders depend on riparian areas for breeding, prey, thermoregulation, and cover. Amphibians can be found inhabiting side channels, oxbows, sloughs, and other aquatic features. A number of reptiles are also dependant on riparian habitat. Aquatic turtles utilize loose soils within riparian areas for nesting. This habitat type is also of particular importance to native gartersnake populations.

Riparian areas provide important direct and indirect influences on Wyoming fish populations and their habitat. At higher elevations, the four native cutthroat trout subspecies and non-game species such as mountain sucker and longnose dace, depend on cool water with low sediment supply from streams with healthy riparian vegetation. Streams like Huff Creek in western Wyoming harbor native fish populations that have fluctuated through time in response to changes in the extent and function of riparian willow communities (Chaney et al. 1991, Binns 1981). Riffle-dwelling species such as longnose dace and riffle-spawning salmonids require relatively smaller, fine sediment levels associated with healthy riparian vegetation. Cottonwood gallery forests, such as those along the Powder River and its tributaries, periodically contribute logs and branches to the river channel which provides cover for fish species such as channel catfish. Woody debris accumulations provide juvenile salmonid habitat and adult overwintering habitat. In the relatively low-productivity waters of the upper Wind River drainage, higher Yellowstone cutthroat trout concentrations are consistently found associated with woody debris.

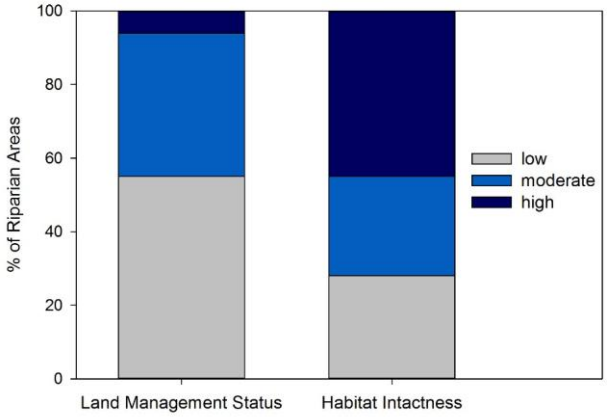
Riparian areas play a critical role in maintaining continuous flow and providing year-round aquatic habitat for fish and other species that occupy the wetted stream channel. Overbank flooding during snow melt in most years saturates riparian soils and elevates adjacent water tables. This underground water storage sustains riparian vegetation during periods when precipitation is scarce and releases water slowly into the stream (Ewing 1978). Though these flows are often small, they maintain water temperatures in suitable ranges for fish, improve water quality, and sustain isolated pools critical for fish survival (Winters et al. 1998).

Riparian Area Threats

Figure 16. Riparian Areas Vulnerability Analysis



The colored bars show the proportion of the habitat type that was identified as having low, moderate, or high vulnerability to climate change or development, based on classification of scores ranging from 0 to 1 into the following categories: low (<0.34), moderate (0.34-0.66), and high (>0.66). Rankings for climate change or development vulnerability were based on the land area of the habitat type classified as having high vulnerability: low (<10%), moderate (10-33%), or high (>33%). Vulnerability was calculated as exposure minus resilience. Development vulnerability includes existing and projected residential, oil and gas, and wind energy development. Further details are provided in the Leading Challenges section of this report and in Pocewicz et al. (2014).



The colored bars show the proportion of the habitat type that was identified as having low, moderate, or high land management status or habitat intactness. For land management status, high corresponds to the percent of the habitat occurring in GAP status 1 or 2, moderate to the percent occurring in GAP status 2b or 3, and low to the percent occurring in GAP status 4. Rankings for land management status were based on the land area of the habitat type classified as having high status or legal protection: low (<10%), moderate (10-33%), or high (>33%). For habitat intactness, scores ranging from 0 to 1 were assigned to categories as follows: low (<0.34), moderate (0.34-0.66), and high (>0.66). Rankings for intactness were based on the land area of the habitat type classified as having high intactness: low (<25%), moderate (25-75%), or high (>75%).

Water development/altered flow regimes - High

Natural flow regimes in stream segments around the state have been altered by human activities including irrigation diversions and water developments for enhanced water supply, hydropower, and flood control. No comprehensive national inventory of riparian conditions or trends exists, but it has been suggested that a minimum of 95% of all western riparian habitats have been altered in some way during the past century (Ohmart 1994). In Wyoming, altered flow regimes are also a consequence of broad-scale changes in land use and management associated with agriculture, grazing, timber harvest, and housing development (see Wyoming Leading Wildlife Conservation Challenges – Disruption of Historic Disturbance Regimes). Flow regimes have been substantially altered in significant portions of major Wyoming waterways including the North Platte River, Green River, Wind River, Bighorn, and Snake River. The Powder River's flow regime, by contrast, is much less altered (Peterson et al. 2009, Hubert 1992).

While water development can threaten native species, some introduced species, including popular sport fisheries, have thrived in the face of water development. The simplification of natural systems by human development tends to favor species with generalized and broad habitat requirements. For example, the walleye fisheries in the North Platte River reservoirs and Boysen Reservoir depend on the consistent deep water and forage production inherent in these man-made water bodies. Stable stream flow releases from dams, with relatively low peak flows and relatively high base flows, perpetuate productive sport fisheries. The famous "Miracle Mile" trout fishery below Kortes Dam and the "Grey Reef" fishery below Alcova Dam are examples.

Water development commonly results in decreased flood frequencies, lower peak flows, and shifts in peak flow timing. In almost all cases, dams reduce peak flows associated with spring runoff and change the timing, duration, and magnitude of the natural hydrograph. Auble et al. (1994) noted that substantial changes in riparian vegetation can occur without changing the mean annual flow because riparian vegetation is especially sensitive to changes in minimum and maximum flows. Bovee and Scott (2002) also observed this phenomenon and noted that changes in peak flows can reduce seedling recruitment and lead to gradual decline of certain riparian woodlands. Mahoney and Rood (1998) described how recruitment of cottonwood seedlings is limited to a narrow zone adjacent to the river—the zone is defined at its upper margin by the limit of overbank flow and at the bottom by the potential for subsequent scouring and deposition. They noted that river water volume must decline gradually so the seedling root growth can keep pace with the capillary fringe above the water table. In Wyoming, cottonwood declines have been noted to follow closely after flow alterations on the North Platte River (Miller et al. 1995) and Bighorn River (Akashi 1988, Bray 1996).

Riparian impacts associated with the loss of high spring flushing flows on dammed rivers greatly reduce the natural cycle of sediment transport and deposition. In addition, levees and bank stabilization structures can also adversely impact riparian systems by confining water to the main stream channel. Levees and other structures that constrain natural stream channels reduce not only floodplain inundation and maintenance but also the channel processes of aggradation and degradation that promote colonization and establishment of native willows and cottonwood trees.

Conditions that restrict or limit the establishment and maintenance of native cottonwoods and willows can cause the riparian vegetative communities to transition toward communities dominated by non-native Russian olive and tamarisk (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). Though these invasive, non-native tree species provide habitat for some organisms, their structure and ecological function are different from native riparian vegetation communities. As in most cases, when the core

habitat changes, the animal species and other community components change as well. Reduction in the size and structural complexity of cottonwood stands, through a lack of tree regeneration, has been associated with declines in riparian bird species diversity (Slater 2006).

Reductions in seasonal flooding, whether by storage of high flows in dams, diversion of flow for out-of-channel purposes, or levee construction, often leads to establishment of homes, businesses, and recreational areas in the floodplain. Land-use practices associated with human development, such as removal of permanent cover, grazing, row crop agriculture, and urbanization, can accentuate high and low flows and reduce habitat diversity and length of the lateral edge between the terrestrial and aquatic environments (Schlosser 1991). Wetland drainage can increase peak flows and decrease base flows by reducing bank storage (Moore and Larson 1979). Creation of channels and dikes can increase peak flows (Gordon et al. 1992) and accentuate low flows (Karr and Schlosser 1978).

The reduction in beaver number and distribution is another major contributor to altered stream flows. Fur trapping in the 19th century greatly reduced beaver number and extirpated them from many areas. Now, in the early 21st century, beavers have re-occupied most of their historic range, but only at roughly 10% of pre-European-contact densities (Naiman et al. 1988). Beaver ponds accumulate sediment, improve water quality, reduce stream velocities, raise water tables, and increase the size of the riparian zone. These effects create and maintain both terrestrial and aquatic riparian habitats.

The need for additional water for human use will intensify in the immediate future, and that trend will be especially evident in the western U.S. Wyoming Governor Matt Mead has called for additional water development over a ten-year period beginning in 2015 (Wyoming Water Strategy 2015.) Such water development could influence riparian vegetation. The water strategy also includes an initiative to foster stream restoration throughout the state which could yield positive effects on riparian vegetation. The trend in water demand has multi-faceted consequences for fish and wildlife and the habitats upon which they depend. In Wyoming, efforts have already begun to consider trans-basin water diversions. Energy diversification, including hydropower development, may increase as the nation's energy demands rise. Warmer conditions with more erratic precipitation—which some predict for Wyoming's future climate—may heighten the need for additional water development (water storage) for municipal and agricultural purposes. The likely trend will be water development projects closer to the delivery point and conveyance via pipelines instead of stream channels. Additional emphasis will likely be placed on lining irrigation ditches and other practices to more efficiently use water for consumptive purposes. The net effect of all such water management practices will be to reduce intra- and inter-annual variability in Wyoming's streams and associated riparian corridors (see Wyoming Leading Wildlife Conservation Challenges – Climate Change).

Drought and climate change - High

Changes in precipitation patterns under various climate change scenarios are predicted to produce peak flows earlier in the yearly cycle and to lower base flows (Barnett et al. 2004). Such drought conditions can be stressful to riparian habitats. Drought can increase browsing and grazing pressure on riparian areas from-ungulates, thus reducing the vigor and structural diversity of riparian vegetation. Drought lowers water tables, leading to reduced plant growth and reproduction. Lower water levels increase water temperatures and reduce the living space available to fish and other aquatic wildlife. All these conditions can be detrimental to the health and reproductive success of all riparian wildlife species.

In riparian habitats, climate change may increase air and surface water temperatures, alter the magnitude and seasonality of precipitation and run-off, and shift the reproductive phenology and distribution of plants and animals (Seavy et al. 2009) (see Wyoming Leading Wildlife

Conservation Challenges – Climate Change). Riparian habitats will likely play a leading role in wildlife conservation adaptation strategies to climate change by providing travel corridors, including along altitudinal gradients; linking aquatic and terrestrial ecosystems; providing thermal refugia for wildlife; and providing resilience to natural disturbances (Seavy et al. 2009).

In an attempt to mitigate the effects of drought on water supply to users in the lower Colorado River Basin, the System Water Conservation Program was initiated on a pilot basis in 2015 (Wyoming State4 Engineers Office 2015). This program provides payments to water right holders in the Green River Basin that voluntarily reduce water diversions on a temporary basis. In its first year, payments were made to five applicants that chose not to divert during late-season, fallowing their hay fields or pasture. The additional late-season flows may positively affect riparian plant communities, largely comprised of willow and sedges.

Invasive species – High

Tamarisk (commonly known as *saltcedar*) and Russian olive are the two invasive plant species that currently have the most significant negative impact on Wyoming's riparian habitats (see Wyoming Leading Wildlife Conservation Challenges – Invasive Species). Tamarisk is an aggressive colonizer that often outcompetes and can completely replace willows, cottonwoods, and other native riparian vegetation. The stems and leaves of mature tamarisk plants secrete salt which forms a crust above and below ground that inhibits other plants (Sudbrock 1993). Infestations of tamarisk have a detrimental impact on wildlife, as although it provides some shelter, its foliage and flowers provide little food value for native wildlife species.

The problems associated with Russian olive are similar. It can outcompete native riparian vegetation, interfere with natural plant succession and nutrient cycling, and tax water reserves. The spread and establishment of Russian olives has been accelerated by water development projects. These projects have reduced flushing flows and the associated formation of point bars necessary for the regeneration and establishment of native vegetation such as willows and cottonwoods. Although Russian olives can provide food and cover, they typically replace native vegetation favored by many wildlife species. Studies indicate that Russian olives harbor fewer bird species than native vegetation (Brown 1990, Knopf and Olson 1984).

Where Russian olive or tamarisk occurs, the risk of wildfire can increase their detrimental impact. Both species are vigorous sprouters and usually gain the upper hand over native species after a fire. The expansion of Russian olive and tamarisk has reached a point in many Wyoming riparian habitats, especially the low elevation larger stream systems, that expensive restoration efforts are needed to re-establish native riparian shrub communities.

Other invasive species also impact riparian areas including leafy spurge, Dalmatian toadflax, whitetop, Canada thistles, black henbane, and spotted knapweeds. Options to control Russian olive and tamarisk and other invasive species can also negatively impact native vegetation and complicate management of riparian forests.

Ungulate grazing and browsing – High

Proper grazing management can be effective habitat management tools and compatible with riparian area maintenance and improvement. However, improper grazing in riparian areas can eliminate vegetation and associated wildlife, widen stream channels, cause soil erosion, increase water sediments loads, raise water temperature, encourage the spread of invasive species, change stream bank configuration, and lower surrounding water tables (Chaney et al. 1991, Nicholoff 2003). Uncontrolled livestock can congregate in riparian areas where they find water, succulent forage, and favorable microclimates including shade, wind reduction, and higher humidity (Clary and Webster 1989, Belsky et al. 1999).

Overbrowsing by wildlife, especially native ungulates, can negatively impact riparian vegetation. The most notable impacts are from

elk, moose, and white-tailed deer. As with livestock grazing, impacts tend to be site-specific, where herd numbers exceed management objectives, or where animals congregate to escape hunting and other forms of predation, or as a result of other causes. For Wyoming's riparian SGCN, special attention needs to be given to grazing management to ensure that adequate understory vegetation and mid-story shrubs are present. Cottonwood regeneration is important for providing nesting trees including mature decadent trees for cavity nesters.

The WGFD sets big game herd unit population objectives based on a variety of factors including habitat condition within the herd unit, hunter demand, landowner input, and biological potential. These considerations result in mixed opinions as to what the objective should be. All objectives are taken to the public for review and approved by the Wyoming Game and Fish Commission. Although the Wyoming Game and Fish Department (WGFD) collects habitat data across the state, seldom is it specific enough to tie the habitat condition directly back to a specific number of animals. Such data is useful; however, in understanding whether big game populations are within the limits of what the habitat can support. The WGFD strives to have populations that are in balance with the majority of the habitats within the herd unit.

Rural subdivision and development – Locally High / Moderate

The high visual and recreational appeal of riparian habitats results in these habitats being desirable locations for home construction and other forms of human development. Houses, outbuildings, and lawns directly replace native wildlife habitat. Wildlife commonly abandon or alter their use of habitats with greater human and pet activity. Increased energy expenditures or greater use of lower quality habitats in order to avoid people can decrease animal health and reproductive capacity. Greater road densities and traffic volume can increase wildlife–vehicle collisions. Predation on wildlife can intensify with greater numbers of dogs and cats, as well as increasing numbers of generalist predatory species such as ravens. Soil disturbance from construction, the year-round grazing of horses and other hobby livestock, and the use of non-native plants as ornamentals can facilitate the establishment of invasive species (Maestas et al. 2002). Pesticide and herbicide concentrations may increase in runoff from nearby lawns. Loss of agricultural operations to rural residential development can result in a loss of irrigated meadows that are important to many wildlife species (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development).

Due to the limited size and distribution of riparian habitats relative to other landscape features and their critical role as corridors for both aquatic and terrestrial species, fragmentation of this habitat can severely compromise its value for wildlife. Maintaining the integrity of riparian areas will become increasingly important in preparing for the possible influence of climate change to enable species to travel to more suitable habitats as ecosystems change (see Wyoming Leading Wildlife Conservation Challenges – Climate Change). Riparian areas in relatively lower elevation areas in Wyoming (e.g., around Cheyenne, Star Valley, and the Snake River) are at greatest risk for future change due to rural development (Copeland et al. 2010).

Incompatible energy development practices - Moderate

Energy development can result in the direct removal of native vegetation and habitat fragmentation through road building, well pad drilling, power line construction, buried pipelines, booster stations, and facility buildings. Habitat fragmentation and loss also occurs indirectly through increased traffic and noise. Greater amounts of disturbed or bare ground, as well as greater vehicle traffic associated with the construction and production phases of energy development, can contribute to the spread of invasive plant species (see Wyoming Leading Wildlife Conservation Challenges – Energy Development).

Energy development can have a variety of effects on stream and lake hydrology and water quality. There can be drawdowns of streams and ponds by tanker trucks for water use at well sites. Surface discharge of poor quality ground water, as a byproduct of coalbed methane (CBM) extraction, can raise salinity levels and negatively impact riparian and aquatic organisms. Salts from CBM-produced water can accumulate in the roots of riparian vegetation and upper soil layers, stunting plant growth. CBM discharge water can also negatively affect the movement of water into and through soils and limit plant hydration. Changes in flow regimes and soil salinity may facilitate the replacement of native species by invasive species including tamarisk, Russian olive, and leafy spurge.

Runoff from roads and construction sites can reduce water quality through higher sedimentation and contamination from spills. Riparian areas in southwest and northeast Wyoming are at a relatively higher risk from future oil and gas development (Copeland et al. 2010).

Current Riparian Conservation Initiatives

Some habitat improvement programs, which can apply to riparian habitats, are covered in the 2017 SWAP wetlands habitat type.

Collectively, several ongoing activities in Wyoming are maintaining or improving riparian areas. Individual habitat protection and restoration projects, provide significant benefits. Federal Farm Bill programs and the agencies that implement them are actively working to benefit riparian areas. All of these efforts are possible only through the interest and cooperation of private landowners. Water management actions, both by individual irrigators and by federal and state agencies, are at times benefitting riparian areas. Instream flow water rights provide an ancillary riparian protective benefit. Comprehensive water planning efforts through the Wyoming Water Development Office are ongoing and include riparian elements. Finally, protection of existing riparian areas through careful development practices is promoted through the consistent and thorough environmental commenting practices of the WGFD.

In 2015, Wyoming Governor Matt Mead unveiled a Water Strategy that includes a river restoration initiative (Mead 2015). This initiative is to develop strategies, financial tools, technical expertise, and collaborative agreements that further stream restoration efforts throughout Wyoming. Cooperating agencies include the WGFD, Wyoming Department of Agriculture, Wyoming Wildlife and Natural Resource Trust Fund, and the Wyoming Department of Environmental Quality. Recommendations, agreements, education, outreach, and guidelines will be developed under this effort and undoubtedly benefit riparian resources.

Many riparian habitat improvement, management, and protection projects have been conducted in recent years under the direction of the WGFD's Strategic Habitat Plan (SHP). For

example, the WGFD, working with conservation partners, completed 14 projects on 309 acres in 2014 specifically focused on riparian habitat protection, enhancement, and management (Wyoming Game and Fish Department 2014). On average, every year WGFD is involved in 18 projects protecting or enhancing over 760 acres of riparian habitat. Projects often entail establishing woody plants like cottonwood and willows (Anderson 2009). In 2014, six beavers were transplanted to augment and improve riparian function. On average, 10 beavers are moved annually to promote riparian benefits. In 2015, a pilot effort began to test a Beaver Restoration Assessment Tool (BRAT; Wheaton and McFarlane 2014) in the Green River Basin. The tool uses GIS data to model historic and current day beaver habitat to identify best locations to move beaver. This approach has been used extensively in Utah and may be applied across Wyoming pending the outcome of the pilot work.

Annual WGFD habitat reports, such as Wyoming Game and Fish Department 2014, have been produced since 2003 and highlight hundreds of projects completed to benefit riparian and other habitats. Many of these projects contain a component funded by the Wyoming Game and Fish Department Trust Fund, established in the late 1980s and now yielding over $1 million annually for habitat restoration work.

Another and more significant funding source is the Wyoming Wildlife Natural Resources Trust (WWNRT). Beginning with the first allocation of project dollars in June 2006, the WWNRT has funded 538 projects in all 23 counties of the state (Wyoming Wildlife and Natural Resource Trust 2015). Over $58 million has been allocated from WWNRT funds, with a total project value on the ground in excess of $343 million. A substantial portion of these WWNRT-funded projects protect and enhance riparian habitats across Wyoming.

The WGFD's SHP recognizes riparian habitat maintenance, protection, management, and restoration priorities (Wyoming Game and Fish 2015) with specific goals and objectives. Regional priority areas for conservation work are identified, many of which include a specific focus on riparian areas and issues (https://wgfd.wyo.gov/Habitat/Habitat-Plans/Habitat-Priority-Areas). For example, in the Cody region, riparian areas were prioritized as *crucial* areas and *enhancement* areas. These priority areas encompass broad portions of the Bighorn River and tributaries, and actions to maintain or improve riparian values and issues are identified in specific narratives (e.g., https://wgfd.wyo.gov/Habitat/Habitat-Priority-Areas/Statewide-Maps/Cody).

The Environmental Quality Incentives Program (EQIP) is the United States Department of Agriculture (USDA) Farm Bill program which provides resources and assistance to landowners to implement riparian habitat improvement projects and grazing plans. The Continuous Conservation Reserve Program (CRP) program administered by the Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS) creates buffer zones along riparian areas that exclude grazing on a 10–15-year contract basis. Regional Conservation Partnership Program (RCPP) is a new program under the 2015 farm bill to promote coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. In Wyoming, three RCPP projects were initiated in the first year of the program and all will benefit riparian resources (NRCS 2015; https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wy/programs/farmbill/rcpp/?cid=nrcseprd373042).

The U.S. Army Corps of Engineers (Corps) and an interagency review team (IRT) recently developed a Wyoming Stream Mitigation Procedure (USACE 2013). This procedure describes a method for quantifying stream losses (debits) and the acceptable compensatory mitigation (credits) for permitted projects in Wyoming. The method has been applied in the 2015 development of the first stream mitigation bank in Wyoming. The bank includes riparian restoration and protection along several miles of

the Sweetwater River. The IRT is further developing a tool to quantify functional improvements, including those in the riparian zone, associated with stream restoration projects. It is anticipated this tool will become widely used beyond the permitting arena to formulate objectives, compare restoration proposals, and communicate benefits associated with stream restoration. The key four functional attributes to be measured include riparian, floodplain connectivity, lateral stability, and channel diversity.

Together with the Bureau of Reclamation, State Engineer's Office, and Wyoming Water Development Commission (WWDC), the WGFD has worked to develop formal and informal water management strategies for managing some reservoirs. These agreements benefit aquatic wildlife, including sport fisheries, while still serving the project's legislatively authorized purposes. Examples include the Snake River below Jackson Lake Dam; Shoshone River below Buffalo Bill Dam; Green River below Fontenelle Reservoir; Bighorn River below Boysen Reservoir; and the North Platte River below Kortes, Pathfinder, Grey Reef, and Glendo Dams. Any benefits to riparian areas that accrue; however, are secondary to a traditional focus on flow releases to benefit sport fisheries and recreation. Release schedules specifically tailored for riparian habitat have not been identified or implemented.

Water management associated with traditional agricultural flood irrigation practices is often cited by ranching interests as beneficial for riparian zone maintenance. There is no doubt that riparian areas in some areas are locally created and maintained through irrigation practices though a formal and systematic evaluation of such riparian areas has not been conducted. Riparian vegetation communities can be strongly influenced by the type, timing and extent of irrigation. Conversion from flood to center pivot has been known to change riparian characteristics. Technological changes like side role systems and gated pipe deliver water more efficiently to agricultural crops and have the potential to conserve water for other uses like maintaining stream flows. The influence of improved irrigation efficiency on riparian characteristics is complex and dependent on site characteristics.

Instream flow water rights provide some certainty that the state can protect natural flow regimes up to designated base levels for fisheries and, by association, may benefit riparian corridors along instream flow segments. The WGFD began evaluating various methods and quantifying instream flow needs for fish in 1979. In 1986, the state legislature enacted a statute (41-3-1001 to 41-3-1014) that formally recognizes opportunities to maintain or improve instream flow as a "beneficial use." Because water rights can only be issued for uses that have been officially recognized as "beneficial", this designation is of critical importance. Since inception of the water right program, the WGFD has employed two (and at times three) full-time biologists to identify priority areas and quantify instream flow regime needs for fish habitat. Additionally, the WGFD has assisted in developing more than 140 instream flow water rights applications through the WWDC. A plan guiding instream flow efforts is at (https://wgfd.wyo.gov/WGFD/media/content/PDF/Fishing/ISF_WATERMGMTPLAN.pdf). Under this plan, instream flow water rights will continue to be pursued to protect fisheries.

The state has undertaken a comprehensive water planning effort that, while not focused directly on riparian habitats, closely relates to the fate of riparian areas in Wyoming. The 1999 Legislature approved the recommended planning framework and authorized the Bear and Green River Basin Plans (Wyoming Water Development Office 2010). In the years that followed, the Legislature authorized funding for the five remaining river basin plans. The Platte River Basin Plan was the last plan completed in May 2006. Anticipating completion of the individual river basin plans, the 2005 Legislature authorized funding for the Statewide Framework Water Plan. The purpose of this plan was to summarize the results of all seven

river basin plans and provide recommendations for future updates. The plan includes an inventory of the state's water resources and related lands, a summary of the state's present water uses, a projection of future water needs, and an identification of alternative decisions to meet the indicated future water needs. It also provides future water resource planning direction to the State of Wyoming. Since the 2010 SWAP, river basin plans have either been updated or are in the process of being updated in all seven Wyoming river basins.

Mapping of invasive species is ongoing throughout much of the state by county, state, and federal agencies along with private landowners. County cost-sharing programs are available to help landowners control invasive plant species. A number of large, multi-agency cooperative projects are focused on controlling Russian olive and tamarisk and replacing them with native vegetation. Notable projects include Yellowtail, Shoshone River, Shell Valley, and Grass Creek Coordinated Resource Management Teams (CRMs). Along the North Platte River near the communities of Glenrock and Torrington, and along the medicine Bow River, similar large treatment projects have occurred to treat tamarisk and Russian olive with partnerships including conservation districts and weed and pest districts. In another example, the WGFD is working with Seedskadee National Wildlife Refuge, the Wyoming Landscape Conservation Initiative, the community of Green River, landowners, and others, to map and treat Russian olive and tamarisk infestations along the Green River below Fontenelle Reservoir in southwest Wyoming. Riparian issues and efforts along the North Platte River are highlighted in a 2011 documentary (McMillen 2012).

The WGFD has an environmental protection role to maintain wildlife habitats, including riparian areas, and the Department provides comments on the anticipated effects of proposed developments. A WGFD document outlines Best Management Practices (BMPs) and monitoring practices to detect sediment and runoff issues from the roads and stream crossings associated with wind energy development (2010a). Similar approaches for avoiding or mitigating impacts to riparian zones associated with oil and gas development were also developed (2010b). For example, no surface occupancy and a 500-foot buffer zone around riparian areas are recommended. Under the Commission's mitigation policy, riparian habitats are recognized under the mitigation category "High" and the Department promotes measures to result in no net loss of habitat function (WGFD 2012).

The success of ongoing and enhanced riparian conservation and restoration work in Wyoming will depend on the interest and commitment of private landowners. European settlers were attracted to riparian areas to develop farms, ranches, and town sites because of the rich soils and relatively flat topography. Today, some of the most extensive riparian areas, especially in eastern Wyoming, occur on privately held lands. With continued cooperation and communication, projects that benefit riparian areas and their host of wildlife species, while at the same time benefiting the landowner's interest, can continue or even accelerate.

Recommended Riparian Conservation Actions

Continue implementing riparian habitat management, treatment, and protection projects.

- Treat decadent stands to promote regeneration and re-establish lost species and cover through planting and seeding.
- Promote or mimic natural disturbances such as seasonal flooding, erosion, and deposition.
- Encourage riparian buffers to promote regeneration.
- Remain actively involved with various partners, CRMs, initiatives, and programs.

Enhance efforts to control riparian area invasive species.
Specific actions to more effectively control riparian invasive plant species include:

- Increase coordination between agencies and private landowners, especially Weed and Pest Districts, to better align goals and priorities.
- Coordinate with water management agencies such as the WWDC and the Bureau of Reclamation to identify and implement water management strategies to create, maintain, or restore riparian vegetation communities along streams below existing dams. Special effort should be employed to include favorable flow regimes as part of the annual operating plans for new dams or diversion projects in the future.
- Increase legislative funding for removing riparian invasive plant species and re-establishing native willow and cottonwood stands through Weed and Pest Districts and Conservation Districts.
- Improve mapping of the location and spread of invasive species infestations to assist in prioritizing sites for treatment. This information should be captured centrally through GIS and should be made available publicly.
- Enhance landowner, agency, and public awareness and knowledge about riparian invasive species and control techniques. Focus special attention on communicating:
  - the value of seasonally appropriate flood irrigation in riparian corridors
  - the importance of protecting native willow and cottonwood stands
  - the negative impacts of Russian olive and tamarisk and the need to control those species whenever possible
- Follow WGFD Russian olive management guidelines and project ranking scheme to direct project funding and activities to important riparian areas where the greatest benefits will accrue.

Support research on instream flow and overbank flow regimes.
Research on instream flow and overbank flow regimes is needed to facilitate the management of native willow and cottonwood communities. Additionally, research on water uptake and bank stability characteristics of riparian plant species, especially tamarisk and Russian olive, would be beneficial for riparian area management.

Increase GIS mapping of riparian areas.

- Update and make available through online sources spatially explicit riparian priority sites found in WGFD's Strategic Habitat Plan. Long-term riparian inventory and mapping as to the quality and vulnerability of riparian habitats will help managers prioritize future habitat protection and improvement projects and target SGCN conservation activities. Emphasize designing mapping efforts to support maintaining the connectivity of riparian habitats. Retaining the role of riparian habitats in providing travel corridors for wildlife will become an increasingly important component of effective mitigation plans for human development as well as climate change. Riparian corridors are critical to supporting the seasonal migration of wildlife and to retaining the future ability of wildlife to relocate to more suitable habitats. The WGFD will continue to work with the Wyoming Geographic Information Science Center (WyGISC) on various modeling and mapping efforts associated with riparian systems.

Continue developing techniques that minimize negative impacts of energy development and reward the implementation of existing best management practices to maintain or restore riparian communities and habitat.

- In mitigation plans, stress avoiding biologically sensitive areas within project sites and direct off-site mitigation funds to nearby high-value wildlife locations.

- Continue researching behavioral and population responses of riparian species to energy development, including wind.
- Encourage implementation of mitigation measures and/or best management practices as detailed in the Wyoming Game and Fish Commission documents *Recommendations for development of oil and gas resources within crucial and important wildlife habitats* (Wyoming Game and Fish Department 2010c) and *Wildlife protection recommendations for wind energy development in Wyoming* (Wyoming Game and Fish Department 2010b).
- Review and update riparian setbacks and buffer recommendations and identify specific buffers for sensitive fish, amphibians, reptiles, birds, or mammal species as outlined in the WGFD *Recommendations for development of oil and gas resources within crucial and important wildlife habitats* (2010c). Compare Wyoming buffer recommendations to those used in other western states and consider new approaches for addressing buffer width for energy development.
- Review management actions proposed by state and federal agencies involving riparian habitats, and work closely with the Wyoming Governor's office, industry, private land owners, and agency staff during early stages of energy development project planning.

Provide incentives, planning, and technological improvements to enhance livestock management in riparian habitats.

- Additional incentives, including financial, planning, and technical assistance, should be provided to encourage private landowners to participate in projects to improve the natural function and wildlife habitat values of riparian habitats. The Environmental Quality Incentives Program (EQIP) is a USDA Farm Bill programs which already provide some resources and assistance to landowners to implement riparian habitat improvement projects and grazing management plans. The WGFD trust fund program and Fish Wyoming program also provide assistance.
- Research should be conducted to enable federal grazing lease regulations to be more outcome-oriented as opposed to prescriptive in achieving desired riparian habitat conditions. This would encourage greater innovation and adaptation to local site conditions.
- Develop more forage reserves to assist in implementing habitat improvement projects. Forage reserves operate by providing ranchers access to substitute land or forage in order to allow rest from grazing, or the establishment of habitat improvement projects, on land they currently own or rent for grazing.
- Implement riparian grazing recommendations in the *Wyoming Bird Conservation Plan, Version 2.0* (Nicholoff 2003).

In cooperation with land management agencies and private landowners, reintroduce beavers into stream systems where they have been extirpated or occur at low densities and have appropriate food, security, and dam-building vegetation.

- Beaver dam-building activities can increase the size and quality of riparian habitats for both terrestrial and aquatic species (see Wyoming Leading Wildlife Challenges – Disruption of Natural Disturbance Regimes).
- Use the Beaver Restoration Assessment Tool (BRAT) in the Green River basin to evaluate this method for identifying restoration options. Apply the BRAT statewide if deemed appropriate.
- Update WGFD Habitat Extension Bulletin 38, "The Role of Beaver in Riparian Habitat."

- Participate in a Beaver Restoration Project consisting of regional dialogue about beaver best practices and applications hosted by the Association of Wetland Managers and the Association of Fish and Wildlife Managers.

Continue efforts to manage native ungulate populations to avoid overbrowsing of riparian habitats.

- Continue and enhance local efforts to identify sustainable stocking rates of native ungulates and keep populations within established herd objectives. High concentrations of elk, moose, and white-tailed deer, in particular, can cause damage to riparian areas. Accomplishing this goal will include maintaining hunting opportunities, especially on private land, and increasing educational efforts about the importance of doe and cow harvest for population management.
- Maintain or increase landowner cooperation in managing big game herd numbers since animals can congregate on lands where hunting is prohibited or limited. Specialized hunting seasons with weapons that have reduced trajectories, including archery, muzzleloader, and shotgun seasons, may be needed in some areas. Public education about the purpose and value of these seasons in locations close to residential areas may be needed.

Increase educational efforts about the ecological, economic, and social values of riparian habitats and associated conservation tools and management techniques.
Enhance educational efforts in the following key areas:

- Increase awareness among natural resource agency employees about the importance of historic flow regimes to properly functioning aquatic systems, riparian habitats, and riparian wildlife species.
- Increase knowledge levels about the threat of invasive plant species, particularly Russian olive and tamarisk, to riparian habitats and wildlife.
- Continue to improve private landowner awareness of opportunities to jointly improve livestock, water, and wildlife habitat management. Marketing programs could:
  - Survey, on a regular and systematic basis, specific target audiences to determine their views, values, and knowledge of riparian issues and opportunities.
  - Maintain an up-to-date website with regular, focused messages about riparian issues and opportunities.
  - Develop targeted audience email lists to provide needed information (based on surveys) about riparian issues, funding opportunities, and WGFD assistance.
  - Develop reference materials for managers and landowners.

Enhance coordination among natural resource agencies, private landowners, and nonprofit conservation organizations to identify and implement shared riparian habitat management objectives.

- Use the existing workgroup assembled to implement the River Restoration Initiative under the Governors Water Strategy to retain a focus on riparian benefits associated with river restoration.
- Enhance coordination through development of an interagency riparian management task force made up of at least one representative from each state and federal agency with an interest or responsibility for managing riparian habitats.
  - At a minimum, this task force should consist of representatives from each federal land management agency, the Bureau of Reclamation, U.S. Fish and Wildlife Service, State Land Board, Parks and Recreation, State Engineers Office,

Weed and Pest District(s), Wyoming Department of Agriculture, Conservation District(s), private landowner representatives, and appropriate NGO representatives including the Wyoming Stock Growers and Wyoming Wool Growers Associations.

- This group should meet at least annually to discuss riparian trends, priority areas, identify effective management practices, present the results of current research, and share information on the availability of financial assistance for riparian management.
- A critical function of this team should be identifying funding assistance opportunities for private landowners.

- Support and promote research through the University of Wyoming Fish and Wildlife Cooperative Research unit on:
  - Instream flow and overbank flow regimes needed to manage for native willow and cottonwood communities, and
  - water uptake and bank stability characteristics of riparian species, especially tamarisk and Russian olive.

Increase conservation easement acquisition with willing landowners on riparian habitats.

- Increase conservation easement acquisition. A high proportion of Wyoming's riparian habitats are privately owned. Conservation easements are one of the most effective long-term methods of limiting environmentally destructive development and management activities on private lands while retaining ranching, outdoor recreation, and other compatible land uses (see Wyoming Leading Wildlife Conservation Challenges – Rural Subdivision and Development). Land values for riparian habitats are typically the highest of any habitat type. Increased funding for conservation easements will be needed to conserve riparian habitats on a broad scale.

Evaluate avoidance and mitigation options for riparian habitat associated with new water development proposals.

- Coordinate WGFD personnel (Water Management, Statewide Wildlife and Habitat Management, and Habitat Protection) who work with WWDC or other water development interests to specifically quantify riparian habitat impacts and mitigation needs for all new water development projects.

Riparian Monitoring Activities

Continue monitoring riparian SGCN in order to detect population trends or changes in distribution that may reflect habitat problems. This information should be used to guide future monitoring, conservation, and research.

Conduct additional inventory and monitoring work to document the locations of riparian habitats, habitat conditions, and the effects of management actions.
Include the following recommended specific inventory and monitoring activities:

- Monitor the establishment and spread of invasive plant species, particularly Russian olive and tamarisk, in cooperation with Weed and Pest Districts, local conservation districts, private landowners, and other state and federal agencies
- Track the number, type, and location of water development projects on Wyoming rivers and streams and their influence on historic flow regimes and wildlife movement.
- Establish monitoring sites and protocols to evaluate the potential effects of climate change, including its potential influences on flow regimes and assemblages of riparian plants and animals.
- Document sites of vestigial diversity and promote their protection and expansion.

- Establish the probable state, extent, diversity and complexity of pre-settlement riparian forest to provide guidance for restoration efforts.
- Record the location, size, and type of riparian habitat enhancement and conservation projects.
- Quantify grazing and browsing levels by livestock and wild ungulates in key areas of known impact. Target this monitoring to key locations in riparian corridors where disruptions in the riparian corridor affect wildlife movement opportunities over relatively high distances in larger river systems like the Green River, Bighorn River, and Powder River.
- Monitor dam-building success, pond characteristics, riparian vegetation community patterns, and water retention associated with beaver reintroduction efforts.

These monitoring activities can help prioritize sites for habitat improvement and conservation projects, assist with refining riparian management techniques, and contribute to quantifying current successes.

Monitor the landscape distribution and habitat intactness of riparian habitats through remote sensing.
Remote sensing is useful in tracking the size, distribution, and fragmentation level of riparian habitats in Wyoming. This information could help determine the cumulative impacts of activities and events such as rural subdivision, energy development, historic flow regime alteration, and the spread of invasive species. This technique will require the further development of monitoring protocols and the identification of sample sites.

Literature Cited

AKASHI, Y. 1988. Riparian vegetation dynamics along the Bighorn River, Wyoming. M.S. thesis, University of Wyoming, Laramie, WY.

ANDERSON, A. 2009. Bighorn Basin riparian restoration/waterjet stinger. Project Completion Report to National Wild Turkey Federation. WGFD/NRCS Worland, WY.

ANNEAR, T., I. CHISHOLM, H. BEECHER, A. LOCKE, ET AL. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

AUBLE, G. T., J. M. FRIEDMAN, AND M. L. SCOTT. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications 4(3):544-554.

BARNETT, T., R. MALONE, W. PENNELL, D. STAMMER, B. SEMTNER, AND W. WASHINGTON. 2004. The effects of climate change on water resources in the West: introduction and overview. Climatic Change 62:1-11.

BELSKY, A. J., A. MATZKE, AND S. USELMAN. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. J. Soil and Water Cons. 54:419-431.

BINNS, N. A. 1981. Bonneville cutthroat trout *Salmo clarki utah* in Wyoming. Fisheries Technical Bulletin No. 5. Wyoming Game and Fish Department, Cheyenne, WY.

BOVEE, K. D., AND M. L. SCOTT. 2002. Implications of flood pulse restoration for *Populus* regeneration on the upper Missouri River. River Research and Applications. 18:287-298.

BRAATNE, J. H., S. B. ROOD, AND P. E. HEILMAN. 1996. Life history, ecology, and conservation of riparian cottonwoods in North America. Pages 57–85 *in* R. F. Stettler, H. D. Bradshaw, Jr., P. E. Heilman, and T. M. Hinckley, editors. Biology of *Populus* and its implications for management and conservation. NRC Research Press, National Research Council of Canada, Ottawa, ON, Canada.

BRADLEY, C. E., AND D. G. SMITH. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montana. Canadian Journal of Botany 64:1433-1442.

BRAY, T. J. 1996. Changes in channel morphology and riparian mosaics on the Big Horn River, Wyoming. M.S. thesis, University of Wyoming, Laramie, WY.

BROWN, C. R. 1990. Avian use of native and exotic riparian habitats on the Snake River, Idaho. M.S. thesis, Colorado State University, Fort Collins, CO.

BUSKIRK, S. W. 1991. Terrestrial vertebrates in riparian habitats of Wyoming. Proceedings of the riparian workshop. University of Wyoming.

CHANEY, E., W. ELMORE, AND W. S. PLATTS. 1991. Livestock grazing on western riparian areas. Produced for the Environmental Protection Agency by the Northwest Resource Information Center, Eagle, Idaho.

CLARY, W. P., AND B. F. WEBSTER. 1989. Managing grazing of riparian areas in the intermountain region. U.S. Forest Service General Technical Report INT-263.

COLLINS, T. 1993. The role of beaver in riparian habitat management. Habitat Extension Bulletin No. 38. Wyoming Game and Fish Department. Cheyenne.

COPELAND, H.E, S. A TESSMAN, E. H. GIRVETZ, L. ROBERTS, C. ENQUIST, A. ORABONA, S. PATLA, AND J. KIESECKER. 2010. A geospatial assessment on the distribution, condition, and vulnerability of Wyoming's wetlands. Ecological Indicators 10: 869-879.

COWARDIN, L. M., V. CARTER, F. C. GOLET, AND E. D. LAROE. 1979. Classification of wetlands and deepwater habitats of the United States. Publication FWS/OBS-79/31. U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

ELLIS, L. M. 1995. Bird use of saltcedar and cottonwood vegetation in the Middle Rio Grande Valley of New Mexico, U.S.A. Journal of Arid Environments 30:339-349.

EWING, K. L. 1978. Riparian ecosystems: Conservation of their unique characteristics. *In* R. R. Johnson and J. F. McCormack, editors. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Washington, D.C. U.S. Forest Service (General Technical Report WO-12).

FRIEDMAN, J. M., M. L. SCOTT, AND G. T. AUBLE. 1997. Water management and cottonwood forest dynamics along prairie streams. Pages 49–71 *in* F. L. Knopf, and F. B. Samson, editors. Ecology and conservation of Great Plains vertebrates. Springer-Verlag, New York, NY.

FRIEDMAN, J. M., M. L. SCOTT, AND W. M. LEWIS. 1995. Restoration of riparian forest using irrigation, artificial disturbance, and natural seedfall. Environmental Management 19:547-557.

GEBHARDT, R. KRAPF, S. LEONARD, B. MITCHELL, AND J. STAATS. 1998. Riparian area management: a user guide to assessing proper functioning condition and the supporting science for lotic areas. TR1737-15. Bureau of Land Management, BLM/RS/ST-98/001+1737, Service Center, CO.

GEBHARDT, K., S. LEONARD, G. STAIDL, AND D. PRICHARD. 1990. Riparian area management: riparian and wetland classification review. TR 1737-5. Bureau of Land Management, BLM/YA/PT 91/002)1737, Service Center, CO.

GORDON, N. D., T. A. MCMAHON, AND B. L. FINLAYSON. 1992. Stream Hydrology. Chichester, England: John Wiley & Sons.

GREGORY, S.V.,F.J. SWANSON, W.A. MCKEE, AND K. W. CUMMINS. 1991. An ecosystem perspective of riparian zones. BioScience 41:540-551.

HOWE, W. H., AND F. L. KNOPF. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. Southwestern Naturalist 36:218-224.

HUBERT, W.A. 1992. The Powder River - A relatively pristine stream on the Great Plains, *in* Hesse, L.W. Stalnaker, C.B.Benson, N.G. and J.R. Zuboy, eds. Restoration planning for the rivers of the Mississippi River ecosystem: Washington, D.C. National Biological Survey, Biological Report 19, p.387-395.

JOHNSON, R. R., C. D. ZIEBELL, D. R. PATTON, P. F. FFOLLIOTT, AND R. H. HAMRE. 1985. Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, April 16–18, 1985. Tucson, AZ. USDA Forest Service General Technical Report RM-120.

JONES, G. P., AND G. M. WALFORD. 1995. Major riparian vegetation types of Eastern Wyoming. Report to Wyoming Department of Environmental Quality *by* Wyoming Natural Diversity Database.

KARR, J. R., AND I. J. SCHLOSSER. 1978. Water resources and the landwater interface. Science 210:229-234.

KNIGHT, D. H. 1994. Mountains and plains: the ecology of Wyoming landscapes. Yale University Press.

KNOPF, F. L. 1989. Riparian wildlife habitats: more, worth less, and under invasion. Pages 20–22 *in* K. Mutz, D. Cooper, M. Scott, and L. Miller, editors. Restoration, creation, and management of wetland and riparian ecosystems in the American West. Society of Wetland Scientists, Rocky Mountain Chapter, Boulder, CO.

KNOPF, F. L., AND T. E. OLSON. 1984. Naturalization of Russian-olive: implications to Rocky Mountain wildlife. Wildlife Society Bulletin 12:289-298.

KNOPF, F. L., R. R. JOHNSON, T. RICH, F. B. SAMSON, AND R. C. SZARO. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100:272-284.

LEONARD, S., G. STAIDL, J. FOGG, K. GEBHARDT, W. HAGENBUCK, AND D. PRICHARD. 1992. Riparian area management: procedures for ecological site inventory – with special reference to riparian wetland sites. TR 1737-7. Bureau of Land Management, BLM/RS/SC/PT-92/004+1737, Service Center, CO.

MAESTAS, J. D, R. L. KNIGHT, AND W. C. GILGERT. 2002. Cows, condos, or neither: what's best for rangeland ecosystems? Find out how plant communities vary across ranches, ranchettes, and nature reserves in one Colorado watershed. Rangelands 24(6):36-42.

MAHONEY, J. M., AND S. B. ROOD. 1998. Streamflow requirements for cottonwood seedling recruitment: An integrative model. Wetlands 18(4):634-645.

MCCABE, G. J., AND D. M. WOLOCK. 2007. Warming may create substantial water supply shortages in the Colorado River basin. Geophysical Research Letters, 34, L22708, doi:10.1029/2007GL031764.

MCKINSTRY, M. C., W. A. HUBERT, AND S. H. ANDERSON, editors. 2004. Wetland and riparian areas of the intermountain west: ecology and management. University of Texas Press, Austin Texas, USA.

MERRILL, E. H., T. W. KOHLEY, M. E. HERDENDORF, W. A. REINERS, K. L. DRIESE, R. W. MARRS, AND S. H. ANDERSON. 1996. Wyoming Gap Analysis: a geographic analysis of biodiversity. Final Report, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, WY.

McMillen, B. 2012. River of Time Wyoming's Evolving North Platte River. DVD. Insight Creative Independent Productions.

MEAD, M.H. 2015. Leading the Charge: Wyoming Water Strategy. http://waterplan.state.wy.us/plan/statewide/govstrategy/20150115-GovWaterStrategy.pdf.

MILLER, J. R., T. T. SCHULTZ, N. T. HOBBS, K. R. WILSON, D. L. SCHRUPP, AND W. L. BAKER. 1995. Changes in the landscape structure of a southeastern Wyoming riparian zone following shifts in stream dynamics. Biological Conservation 72:371-379.

MONTGOMERY, G. L. 1996. Riparian areas: reservoirs of diversity. U.S. Natural Resources Conservation Service Working Paper No. 13, Northern Plains Regional Office, Lincoln, NE.

MOORE, I. D., AND C. L. LARSON. 1979. Effects of drainage projects on surface runoff from small depressional watersheds in the north central region. Bulletin 99. St. Paul: University of Minnesota, Water Resources Research Center.

NAIMAN, R. J., C. A JOHNSTON, AND J. C. KELLEY. 1988. Alteration of North American streams by beaver. BioScience 38:753–762.

NAIMAN, R. J., H. DECAMPS, AND M. POLLOCK. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3:209-212.

NAIMAN, R. J., H. DECAMPS, AND M. E. MCCLAIN. 2005. Riparia: ecology, conservation and management of streamside communities. Academic Press.

NATURESERVE, 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

NICHOLOFF, S. H., compiler. 2003. Wyoming Bird Conservation Plan, Version 2.0. Wyoming partners in flight. Wyoming Game and Fish Department, Lander, WY.

NRCS. 2015. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wy/programs/farmbill/rcpp/?cid=nrcseprd373042

OLSON, T. E., AND F. L. KNOPF. 1986. Naturalization of Russian-olive in the western United States. Western Journal of Applied Forestry 1:65-69.

OLSON, R. A., AND W. A. GERHART. 1982. A physical and biological characterization of riparian habitat and its importance to wildlife in Wyoming. Wyoming Game and Fish Department, Cheyenne, WY.

OHMART, R. D. 1994. The effects of human-induced changes on the avifauna of western riparian habitats. Studies in Avian Biology 15:273-285.

PETERSON, D.A. P.W. WRIGHT, G.P. EDWARDS, E.G. HARGETT, D.L. FELDMAN, J.R. ZUMBERGE, AND P.DEY. 2009. Ecological assessment of streams in the Powder River structural basin, Wyoming and Montana, 2005-2006. U.S. Geological Survey Scientific Investigations Report 2009-5023.

POCEWICZ, A., H. E. COPELAND, M. B. GRENIER, D. A. KEINATH, AND L. M. WASHKOVIAK. 2014. Assessing the future vulnerability of Wyoming's terrestrial wildlife species and habitats. The Nature Conservancy, Wyoming Game and Fish Department, Wyoming Natural Diversity Database, Lander, Wyoming

PRICHARD, D., J. ANDERSON, C. CORRELL, J. FOGG, K. GEBHARDT, R. KRAPF, S. LEONARD, B. MITCHELL, AND J. STAATS. 1998. Riparian area management: a user guide to assessing proper functioning condition and the supporting science for lotic areas. TR1737-15. Bureau of Land Management, BLM/RS/ST-98/001+1737, Service Center, CO.

ROOD, S. B., AND S. HEINZE-MILNE. 1989. Abrupt downstream forest decline following river damming in southern Alberta. Canadian Journal of Botany 67:1744-1749.

ROOD, S. B., AND J. M. MAHONEY. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. Environmental Management 14:451-464.

——. 1993. River damming and riparian cottonwoods: management opportunities and problems. Pages 134-143 *in* B. Tellman, H. J. Cortner, and M. G. Wallace, technical coordinators. Riparian Management: 2 Common Threads and Shared Interests. U.S. Forest Service General Technical Report RM-226, Fort Collins, CO.

RUDD, W., L. FORREST, F. LINDZEY, S. BUSKIRK. 1986. River Otters in Wyoming. Wyoming Cooperative Research Unit, Research Report 86–02.

SAUNDERS, W. C., AND K. D. FAUSCH. 2006. Improved grazing management increases terrestrial invertebrate inputs that feed trout in Wyoming rangeland streams. Transactions of the American Fisheries Society 136:1216-1230.

SCHLOSSER, I. J. 1991. Stream fish ecology: a landscape perspective. BioScience 41:704-712.

SEAVY, N. E., T. GARDALI, G. H. GOLET, F. T. GRIGGS, C. A. HOWELL, R. KELSEY, S. L. SMALL, J. H. VIERS AND J. F. WEIGAND. 2009. Why climate change makes riparian restoration more important than ever: recommendations for practice and research. Ecological Restoration 27(3):330-338.

SLATER, S. J. 2006. Wyoming's riparian bird communities: issues of scale and human-caused vegetation and landscape change. Dissertation, University of Wyoming, Department of Zoology and Physiology. Snyder, W. D., and G. C. Miller. 1992. Changes in riparian vegetation along the Colorado River and Rio Grande, Colorado. The Great Basin Naturalist 52:357-363.

SUDBROCK, A. 1993. Tamarisk control. I. Fighting back: an overview of the invasion, and a low-impact way of fighting it. Restoration and Management Notes 11: 31-34.

SWANSON, F. J., S. V. GREGORY, J. R. SEDELL, AND A. G. CAMPBELL. 1982. Land-water interactions: the riparian zone. Pages 267–291 *in* R. L. Edmonds, editor. Analysis of coniferous forest ecosystems in the Western United States. US/ISP Synthesis Series 14, Hutchinson Ross Publishing Co., Stroudsberg, PA.

USACE. 2013. Wyoming Stream Mitigation Procedure.

VANNOTE, R. L., G. W. MINSHALL, K. W. CUMMINS, J. R.SEDELL, AND C. E. CUSHING. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. 37:130-137.

WINTERS, T. C., J. W. HARVEY, O. L. FRANKE, AND W. M. ALLEY. 1998. Groundwater and surface water: a single resource. U.S. Geological Survey Circular 1139. Denver: U.S. Geological Survey, Branch of Information Services.

WINWARD, A. H. 2000. Monitoring the vegetation resources in riparian areas. General Technical Report RMRS-GTR-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Wheaton, J.M. and W.W. Macfarlane. 2014. The Utah Beaver Restoration Assessment Tool: A Decision Support & Planning Tool – Manager Brief, Ecogeomorphology and Topographic Analysis Lab, Utah State University, Prepared for Utah Division of Wildlife Resources, Logan, UT, 16 pp.

WYOMING GAME AND FISH DEPARTMENT. 2015. Strategic Habitat Plan. https://wgfd.wyo.gov/WGFD/media/content/PDF/Habitat/Strategic%20Habitat%20Plan/SHP2015_Final.pdf August 2015. Cheyenne, WY.

———. 2014. 2014 Annual report: strategic habitat plan accomplishments. Cheyenne, WY.

———. 2010a. Wildlife protection recommendations for wind energy development in Wyoming. https://wgfd.wyo.gov/WGFD/media/content/PDF/Habitat/Habitat%20Information/Wind%20Energy%20Development/Wildlife-Protection-Recommendations-for-Wind-Energy-Development.pdf. November 2010. Cheyenne, WY.

———. 2010b. Recommendations for development of oil and gas resources within important wildlife habitats. Version 6. Wyoming Game and Fish Department Report. Cheyenne, WY.

———. 2012 Wyoming Water Strategy. 2015. http://waterplan.state.wy.us/plan/statewide/govstrategy/20150115-GovWaterStrategy.pdf

WYOMING STATE ENGINEERS OFFICE. 2015. https://sites.google.com/a/wyo.gov/seo/

WYOMING WATER DEVELOPMENT OFFICE. 2010. Wyoming State Water Plan. http://waterplan.state.wy.us/. April 2010.

WYOMING WILDLIFE AND NATURAL RESOURCE TRUST. 2010. http://wwnrt.state.wy.us/. April 2010.