# Yellowstone River Basin


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## Watershed Description

Three of the nation's major river systems have their headwaters in Wyoming: the Missouri, Colorado and Columbia Rivers. These watersheds provide a natural basis for delineating aquatic conservation areas. Six major watersheds were identified for conservation planning purposes under this State Wildlife Action Plan (SWAP) using hydrographic boundaries and fisheries assemblage and management considerations (Figure 11). These areas are consistent with the aquatic ecosystems identified for freshwater biodiversity conservation worldwide by Abell et al. (2008). The watershed areas are also synonymous with aquatic zoogeographical units and ecological drainage units identified under The Nature Conservancy's (TNC) hierarchical classification framework (Higgins et al. 2005). The watersheds each include one to four sub-regions (4-digit hydrologic unit code [HUC] watersheds). This approach allows the nesting of multiple spatial and temporal scales for planning and prioritizing conservation actions.

The Yellowstone River Basin includes portions of four 4-digit HUC subregions: the Missouri Headwaters in Yellowstone National Park (YNP; Madison and Gallatin Rivers), the Upper Yellowstone (also partly in YNP), the Bighorn River, and the Powder/Tongue River. A total of twenty-nine 8-digit HUC drainages are nested within these. These watersheds span over one-third of Wyoming, covering 34,167 square miles in northern Wyoming's Big Horn, Campbell, Fremont, Hot Springs, Johnson, Natrona, Park, Sheridan, and Washakie counties. Thirty-five percent of the land is privately held. Public land is managed primarily by the Bureau of Land Management (26% of total area), U.S. Forest Service (17%) and the National Park Service (7%). The Wind River Indian Reservation occupies 7% of the area.

From an analysis of the 2010 Version 2.0 National Hydrological Database (NHD) at 1:100,000, there are approximately 38,600 miles of streams in the Yellowstone River basin in Wyoming. This equates to a drainage density of about 1.1 stream miles per square mile land area. About 77% of these stream miles are first or second order streams.

The Wind River rises high in the Wind River Range from headwaters at elevations over 13,000 feet and flows for about 170 miles, through Boysen Reservoir, before emerging from Wind River Canyon. Here its name changes to the Bighorn River, and it flows another 180 miles through Bighorn Basin and Big Horn Lake to cross the Montana state line at an elevation of about 3,600 feet. By volume, the river is the state's second largest (after the Snake River), leaving the state with an average flow of about 3,360 cubic feet per second (cfs) (Wyoming State Geologic Survey 2010). Major tributaries include the Popo Agie, Nowood, Greybull, and Shoshone Rivers (Figure 11). The river is free flowing down to Diversion Dam, a Bureau of Reclamation (BOR) structure completed in 1924 and located 34 miles northwest of Riverton. Further downstream of Riverton, Boysen Reservoir was built at the head of Wind River Canyon in 1953.

The upper Yellowstone River originates southwest of Yellowstone National Park at elevations over 12,000 feet. The Yellowstone River then flows through Yellowstone National Park and into Montana. Major tributaries to the upper Yellowstone River in Wyoming include Thorofare Creek and the Clarks Fork Yellowstone River.

Three forks of the Powder River emerge from canyons on the east side of the Bighorn Mountain Range and merge east of Kaycee, Wyoming to form the Powder River. The Powder River flows for approximately 290 miles in Wyoming before crossing into Montana. The river then flows for another 85 miles before entering the Yellowstone River in Montana. Major Wyoming tributaries include Clear Creek, Crazy Woman Creek, South Fork Powder River, North Fork Powder River, and Salt Creek (Figure 11). The Tongue River is formed from tributaries along the east face of the Bighorn Mountains, and it too joins the Yellowstone River in Montana.

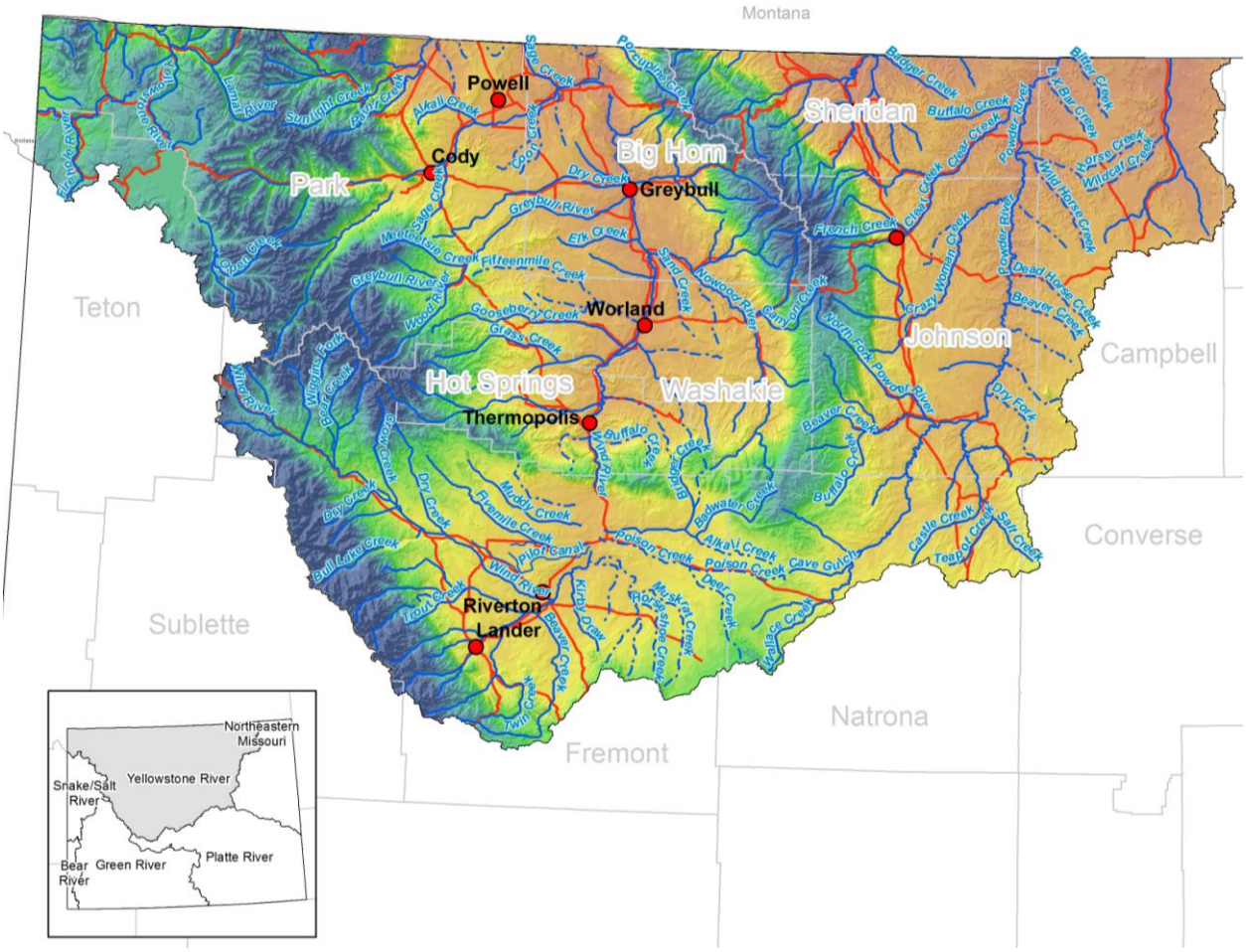


**Figure 11. Yellowstone River Basin.**

The upper Yellowstone River originates southwest of Yellowstone National Park at elevations over 12,000 ft. The Yellowstone River then flows through Yellowstone National Park and into Montana. Major tributaries in Wyoming include Thorofare Creek and the Clarks Fork Yellowstone River.

Three terrestrial-based ecoregions, as defined originally by Bailey (1995) and adapted by The Nature Conservancy, occur in the Yellowstone River basin in Wyoming: Wyoming Basins, Utah Wyoming Rocky Mountains, and Northern Great Plains Steppe east of the Bighorn Mountains. The Bighorn basin is fringed by the Beartooth, Absaroka, Washakie, Owl Creek, Pryor, and Bighorn mountains. The Wind River basin is defined by the Absaroka, Wind River, Owl Creek, and Granite mountains (Lageson and Spearing 1988). Elevations range from 13,804 feet atop Gannett Peak in the Wind River Range, to about 3,320 feet where the Little Powder River departs the state. These mountain ranges have moderate to steep slopes and elevations that feed a snow-melt dominated runoff pattern. Mountainous areas of the Yellowstone Plateau, Absaroka Mountains, Wind River Mountains, and Bighorn Mountains were heavily glaciated. Associated glacial features include abundant small high-elevation lakes, deep U-shaped valleys, tarns, moraines, and cirques (Chapman al. 2004). The high jagged peaks and granite material give rise to boulder, cobble, and bedrock substrates of low biological productivity. The Absaroka

Mountain Range is derived from a relatively recent geologic period of volcanic activity. The range's relative youth, steepness, and erosive material combine to create stream and river systems that are naturally unstable and carry high debris loads (Lageson and Spearing 1988).

The Bighorn Basin has rolling hills, terraces and alluvial fans, and ephemeral stream channels. Nearly level floodplains prevail in some portions of the basin (Chapman et al. 2004). Incised channels are common. In the Powder River basin, topographic features do not reflect glaciation but rather consist of irregular and gently rolling hills. Perennial streams have their source in the Bighorn Mountains which crest at elevations of 8,000–10,000 feet. Streams that arise at lower elevations are often ephemeral and/or intermittent. Substrates are commonly sand, silt, or fine gravel, especially toward the interior of the basin. As streams flow off the impervious igneous and metamorphic rocks of the Precambrian age higher in the Bighorns, they encounter in the foothills Paleozoic and Mesozoic era sandstones, limestones, shale, and Tertiary-age sedimentary rocks (Peterson et al. 2009).

The Yellowstone River basin overlaps three Wyoming climate divisions: number 4 in the Bighorn basin, number 5 in the Tongue and Powder River basins, and number 9 in the Wind River basin (Curtis and Grimes 2004). Climate division 4 has some of the highest spring temperatures, with average monthly values exceeding 43º F in April. For all three climate divisions, average monthly temperatures peak in July near 70º F while January mean temperatures are nearly 20º F (Curtis and Grimes 2004). Monthly precipitation is lowest in December and January and highest in May or June. As little as 6–8 inches of annual precipitation falls within the interior of the Bighorn basin whereas the high surrounding peaks may experience as much as 70 inches annually (Wind/Bighorn Basin Water Plan 2003). Annual precipitation in the Powder basin ranges from about 10 inches to over 30 inches with 13–15 inches over much of the area (Powder/Tongue Basin Water Plan 2002).

Large reservoirs throughout the basin include Big Horn Lake (1,375,000 acre feet storage capacity), Boysen Reservoir (802,000 af), Buffalo Bill Reservoir on the Shoshone River (695,300 af), Bull Lake Reservoir (153,000 af), and Lake DeSmet in the Powder basin (239,000 af) (Jacobs and Brosz 2000). Numerous smaller reservoirs and diversions exist throughout the area (Powder/Tongue River Basin Water Plan 2002, Wind/Bighorn Basin Water Plan 2003). Water development is extensive and plays a large role in patterns of stream flow, especially in streams after they emerge from the mountains. For example, the Bighorn River is highly controlled by dam releases for hydropower, irrigation, flood control, and municipal use. Irrigation diversions and trans-basin diversions further influence water supply.

Miller (2003) delineated six hydrologic regions in Wyoming on the basis of peak flow characteristics. Most of the headwaters in the Yellowstone River basin are in the Rocky Mountains Region under this delineation. As such, streams experience snow-melt runoff and have consistently high peak flows in late spring and early summer. The lowlands within the interior of the Bighorn and Powder and Tongue River basins coincide with the Central basins and Northern Plains Hydrologic Region of Miller (2003). These regions are semi-arid to arid with annual peak flows caused by moderate to very intense rainstorms. Annual peak flows are highly variable year to year. Finally, portions of the upper Powder River drainage and foothills correspond to the Eastern basins and Eastern Plains Hydrologic Region (Miller 2003). These areas have relatively high annual peak flows caused by moderate to intense rainstorm events and variable peak flows between years.

All eleven habitat types defined in this SWAP (e.g., sagebrush shrublands, riparian, etc.,) occur in the watershed and are based on combinations of Ecological Systems (ES) developed by NatureServe (Comer et al. 2003, NatureServe Explorer 2009). The determination and delineation of ES is based on land cover maps produced by the Northwest Gap Analysis Project (NWGAP 2010). Land cover mapping

under NWGAP for the Yellowstone River basin mostly overlaps USGS mapping zones 22 (Wyoming Basins) and 29 (Northern Rocky Mountains) with a smaller portion in mapping zone 21. Of the 173 ES identified under NWGAP, 79 occur in the Yellowstone River basin (excluding developed and open water classes). The most abundant class by far is the Inter-Mountain Basins Big Sagebrush Steppe. This is followed by the Northwestern Great Plains Mixed Grass Prairie. Similarly, the most common SWAP habitats are sagebrush shrublands (41%) followed by montane subalpine forests (14%), desert shrublands (9%), and prairie grasslands (9%). Associated species assemblages, threats, and conservation actions of these and other habitats in this watershed are addressed in separate SWAP chapters.

Covering a large land area in northern Wyoming, land use is very diverse in the Northwestern Missouri River Basin. The Bureau of Land Management (BLM) controls over one-quarter of the surface area from its Lander, Worland, Cody, and Buffalo Field Offices. Resource Management Plans (RMPs) for these districts describe land management direction, resources and allocation of uses (e.g., Bureau of Land Management 1990, 2001). Public lands livestock grazing is a strong traditional and current use both on the BLM districts and in the Bighorn and Shoshone National Forests. Timber harvest, both of saw timber and other products, has been substantial in the Shoshone National Forest, especially following salvage operations in recent years of beetle-killed trees when over 14 million board feet were harvested annually (Shoshone National Forest 2009). The Bighorn National Forest harvests about 4 million board feet annually. Oil, natural gas, and coal deposits in the basins have drawn a long history of mineral development. Coal production in the Powder River basin is extensive and higher than anywhere else in the U.S. In the last 10 years, coal-bed natural gas production has boomed in the Powder River basin. This gas production methodology entails pumping water from deep coal seams to release gas, and the pumped water often has high salt concentrations (Clark and Mason 2007). Uranium mining and bentonite clay mining are additional extractive industries common to the Powder River and Bighorn basins (Chapman et al. 2004).

Water use is dominated by agriculture: 83% and 93% of the water used in the Wind/Bighorn Basin and Powder/Tongue Basin, respectively, is applied toward irrigation (Wind/Bighorn Basin Water Plan 2003; Powder/Tongue River Basin Water Plan 2002). Drylands and particularly irrigated areas of the basins produce a variety of hay, alfalfa, grain and beet crops. Crop irrigation, such as irrigated pasture, by far outweighs other agricultural water uses in the Bighorn Basin, and the area is particularly known for its production of sugar beets (Wind/Bighorn Basin Water Plan 2003). While localized areas of sprinkler use occur, much irrigation throughout the basin is flood irrigation. Unlike in the Bighorn Basin, agriculture in the Powder Basin is more directly linked to forage production for livestock use (Powder/Tongue River Basin Water Plan 2002). Alfalfa, grass hay, and pasture grass are the dominant crops, and they are primarily irrigated with surface water through flood irrigation.

Several waters in the basin are designated by the Wyoming Department of Environmental Quality (DEQ) as class 1, recognizing their outstanding features and protecting them from water quality degradation (Wyoming Department of Environmental Quality, 2001). These waters include the Wind River from Boysen Reservoir to Wedding of the Waters (base of the canyon where the river's name changes to Bighorn River), Middle Fork Powder River upstream of Buffalo Creek, the Tongue River, North Fork Tongue River, and South Fork Tongue River upstream of the U.S. Forest Service boundary, and the Clarks Fork River from the U.S. Forest Service boundary upstream to the Montana state line. Waters in congressionally designated wilderness areas as of January 1, 1999 are also included under the Class 1 designation.

Mirroring the variable underlying geology, landforms, and diverse land use in the basin, water quality characteristics vary dramatically

throughout the basin. In the upper mountainous regions, water quality is generally high but degrades as streams flow out across the lower basins as a result of natural erosion and stream processes which increase sediment and TDS loads (Marston and Anderson 1991, Wyoming Department of Environmental Quality, 2010). Long-term high-density grazing practiced historically in portions of the drainages exacerbated unstable natural conditions and led to gullying and enhanced sediment transport and deposition. Recent extensive beetle-killed lodgepole pine in the Shoshone National Forest is believed to have affected about 63% of forested acres and is likely to change the timing, frequency, and magnitude of runoff events and pattern of sediment and wood delivery to stream channels. Waters currently considered impaired by the DEQ and on the 303 (d) List include: Middle Fork of the Popo Agie River near Lander, Ocean Lake, Poison, and Muddy creeks (Boysen Reservoir tributaries); Kirby Creek, Owl Creek, four small tributaries near the community of Worland, Bighorn River near the communities of Worland and Basin, lower Nowood River, Paintrock Creek, lower Greybull River, Bighorn River below the community of Greybull, lower Shell Creek, and lower tributary segments of Beaver and Granite Creeks, lower Dry Creek, the Shoshone River below Lovell, and seven Shoshone tributary streams between Cody and Lovell, Powder River below Salt Creek, Salt Creek, South Fork Powder River and three small tributaries, North Fork Crazy Woman Creek, lower Crazy Woman Creek, North Piney Creek, Big and Little Goose Creeks and several of their tributaries, lower Tongue River below Goose Creek, North Tongue River, Little Tongue River, Smith Creek, and Prairie Dog Creek. Contaminants are largely fecal bacteria (especially near communities), sediment, and, in the Powder River drainage, salt and selenium.

## Aquatic Wildlife

### Fish

The first reports of fishes in the Yellowstone River basin pertain to cutthroat trout. Yellowstone cutthroat trout have been known from the waters of the Yellowstone River basin in Wyoming since the early military expeditions in the 1800s. Raynolds (1868) reported catching "mountain trout" in the Wind River near the confluence of the Popo Agie. In 1877, the Hayden expedition reported that "In the head-drainage of the Sweetwater not a trout can be found, while in that of Green River, as well as Wind River, they occur in large quantities" (Dorn 1986). The most famous early accounts of Yellowstone cutthroat trout are from the eastern edge of the species historic range on the Tongue River and Big Goose Creek where General Crook spent the month of July 1876. Bourke (1891) reports on the "enormous quantity" of trout angled from these streams and states that the troops captured well over 15,000 trout by hook and line in a three-week period. Bourke (1891) also describes the native Shoshone people capturing gunny sacks full of trout with fish traps constructed of willows. These and the many other early accounts leave little doubt that this subspecies of cutthroat was historically widespread and abundant throughout many of the rivers, streams, and lakes of the Yellowstone River basin.

By the time Everman and Cox visited the Tongue River in 1893, trout fishing pressure was so extreme they reported that "Small parties have reported as many as 800 fish taken with hook and line in a few days. There is so much fishing done now in that region that most residents are of the opinion that if something is not done to stock the stream its fame as a fishing resort will soon be lost" (Everman and Cox 1896). Everman and Cox did not venture west of the Tongue River drainage, but visited multiple waters in the Tongue drainage as well as Clear Creek and the mainstem Powder River at Arvada. They include some of the first detailed descriptions of the non-salmonid fish community of the Tongue and Powder River drainages (Everman and Cox 1896). In the

Powder River, they sampled channel catfish, shorthead redhorse, mountain sucker, sauger, stonecat, white sucker, longnose sucker, plains minnow, fathead minnow, sturgeon chub, flathead chub, and goldeye. In the Tongue River drainage, they documented Yellowstone cutthroat trout, mountain whitefish, mountain sucker, white sucker, longnose sucker, longnose dace, and creek chub and noted that introduced brook trout were also present.

The presence of brook trout in the Tongue River drainage in 1893 (Everman and Cox 1896) is evidence that fish stocking has been influencing fish communities in the Yellowstone River basin for nearly 120 years. Trout stocking began in the upper Wind River in 1899 (Roth 2000), in 1915 in the Greybull River, and in 1919 in the Shoshone River drainage (Kruse 1995). Most streams with habitat suitable to support trout received annual plants of either fingerling brook, brown, rainbow, or Snake River cutthroat trout (Kent 1975a). A total of 21 sport fishes and 10 nongame fishes have been introduced to the basin (Table 11). Most introductions were conducted by the WGFD, but others have been inadvertent or illegal. The known fish assemblage of the Yellowstone River basin is shown in Table. 11. Seven game species and 16 nongame species are believed to be native to the basin. Eleven of these are currently considered SGCN.

**Table 11. Fishes present in the Yellowstone River Basin. Species of Greatest Conservation Need (SGCN) are followed by an asterisk (*).**

| Native game | Native nongame | Nonnative game | Nonnative nongame |
|---|---|---|---|
| Burbot* | Brassy minnow* | Bear River cutthroat trout | Brook stickleback |
| Channel catfish | Creek chub | Black bullhead | Common carp |
| Mountain whitefish* | Fathead minnow | Black crappie | Emerald shiner |
| Sauger* | Flathead chub* | Bluegill | Golden shiner |
| Shovelnose sturgeon* | Goldeye* | Brook trout | Goldfish |
| Stonecat | Lake chub | Brown trout | Grass carp |
| Yellowstone cutthroat trout* | Longnose dace | Colorado River cutthroat trout | Johnny darter |
| | Longnose sucker | Golden trout | Mottled sculpin |
| | Mountain sucker | Grayling | Plains killifish |
| | Plains minnow* | Green sunfish | Spottail shiner |
| | River carpsucker | Lake trout | |
| | Sand shiner | Largemouth bass | |
| | Shorthead redhorse | Pumpkinseed | |
| | Sturgeon chub* | Rainbow trout | |
| | Western silvery minnow* | Rock bass | |
| | White sucker | Smallmouth bass | |
| | | Snake River cutthroat trout | |
| | | Splake | |
| | | Walleye | |
| | | White crappie | |
| | | Yellow perch | |

The Bighorn/Wind River drainage has also been impacted by the construction of three large reservoirs; Boysen and Buffalo Bill reservoirs and Big Horn Lake. In 1908, Asmus Boysen, a Wyoming businessman, constructed the first dam on the Bighorn River about 18 miles south of Thermopolis to operate a small hydroelectric plant which supplied towns in the area. After about 15 years of operation, the dam silted in and was breeched and abandoned. Part of the original dam was removed in 1925, which provided for upstream fish passage. The remainder of the dam was removed in 1948. Before the dam was completed in 1908, thousands of sauger were captured each year above the dam site. Simon (1951) reported that "During the time in which the dam blocked the river channel against migration of fish, saugers were rarely caught above it; but since the dam was destroyed, sportsmen above the canyon again enjoy angling for this excellent fish."

Buffalo Bill Dam was the next dam constructed on a major river in the Yellowstone basin in Wyoming. Buffalo Bill Dam, on the Shoshone River about six miles upstream from Cody, Wyoming, is one of the first high concrete dams built in the United States. It was constructed from 1905–1910, backing up the waters of the North and South Fork Shoshone rivers, as part of the Bureau of Reclamation's earliest irrigation projects. The Buffalo Bill Dam has been modified numerous times, most recently in 1994 when the height was raised 25 ft, providing storage of up to 646,600 acre-feet of water.

Simon (1951) sampled 13 sites in the Powder and Tongue River drainages, 18 in the Bighorn/Wind river drainage, and 1 in the Clarks Fork drainage. This was the first detailed survey of native fishes in the Bighorn/Wind River drainage. By 1950, 21 of 23 native fishes had been documented in the basin. Only the western silvery minnow and sand shiner had not yet been collected in the Yellowstone River basin.

A second, much larger dam was constructed by the Bureau of Reclamation as part of the Pick-Sloan Missouri Basin Program about 1.5 miles upstream of the original Boysen dam site on the Bighorn/Wind River. The new Boysen Dam was completed in 1952 and is a rock and earthfill structure 220 feet high and 1,143 feet long that can impound 952,400 acre-feet of the Wind River. Wilhite (2007) describes the long-term influence of reservoir operation on riverine and riparian habitat downstream.

Construction of the third largest dam in the Yellowstone River basin, Yellowtail Dam, began in 1961 and was completed in 1967. Yellowtail Dam was built on the Bighorn River at the mouth of Bighorn Canyon in Montana, creating Big Horn Lake about 180 river miles downstream of Boysen Dam. The lake is about 72 miles long at maximum water surface elevation, extending into the Bighorn Basin of Wyoming. The reservoir is confined in the canyon for most of its length.

Channel catfish from the southern United States were stocked in the lower Bighorn River and/or Big Horn Lake for at least 15 years beginning in 1960 (Kent 1977) to establish a fishery in the new impoundment. Stocking has since been eliminated due to concerns about potential genetic differences between channel catfish native to Wyoming and those that are introduced from other portions of the species' range. Many other species have been stocked to develop sport fisheries in these reservoirs and in other waters of the Yellowstone River basin (Table 11). For example, walleye and rainbow trout sustain a popular sport fishery in Boysen Reservoir.

Although these three reservoirs provide important sport fisheries for introduced and native species, they have also altered downstream habitats and obstructed movements to the detriment of some native fishes, including shovelnose sturgeon, sturgeon chub, western silvery minnow, and goldeye. Simon (1951) stated that shovelnose sturgeon had been reported from the Powder River drainage and the Bighorn River near the Montana state line. Shovelnose sturgeon are known to migrate hundreds of miles from the Yellowstone River in Montana to spawn in lower Crazy Woman Creek (Annear 1992) and the Powder River immediately below this

tributary. Sturgeon spawning movements into the Bighorn River drainage in Wyoming were blocked by Yellowtail Dam, and this SGCN disappeared from the Bighorn drainage in Wyoming. In 1996, the Wyoming Game and Fish Department began reintroducing shovelnose sturgeon in the Bighorn River and the downstream portions of the Nowood River, Greybull River, and Shell Creek (WGFD 1997). Nearly 390,000 shovelnose sturgeon were stocked between 1996 and 1998 (WGFD 1999). Stocking was curtailed for a number of years beginning in 1999 due to the appearance of iridovirus in the federal hatchery system. Limited stocking resumed from 2006–2009 and will continue depending on the availability of fish from out-of-state sources.

The shovelnose sturgeon belongs to an assemblage of fish species adapted to river habitat with relatively unstable substrate and high turbidity. This assemblage includes the flathead chub, sturgeon chub, goldeye, plains minnow, and western silvery minnow (Baxter and Stone 1995) and is disappearing from Wyoming waters that have been heavily impacted by reservoir construction. These species have all disappeared from the North Platte River, with the possible exception of the flathead chub. Historically, the flathead chub, sturgeon chub, goldeye, and plains minnow were documented in the Bighorn River (Simon 1951), and western silvery minnow were abundant between Wind River Canyon and the Montana state line before the construction of Yellowtail Reservoir (Baxter and Simon 1970). Only the flathead chub appears to be secure in the Bighorn drainage (Bear 2009), although Patton (1997) found that the distribution and abundance of this species had declined significantly in the Missouri drainage since the 1960s. Kent (1977) caught three plains minnow in the Bighorn River in the early 1970s, and Patton (1997) reported this species from the lower mainstem Shoshone River. The species has not been observed since. Sturgeon chub were last sampled in the Bighorn River in 2001. The goldeye, plains minnow, sturgeon chub, and western silvery minnow are disappearing from the Bighorn drainage and may in fact, have been extirpated. In Wyoming, this unique assemblage of fishes remains largely intact only in the free-flowing Powder River drainage. Although rare, sturgeon chub and western silvery minnow are still found in the Powder River. Flathead chub, plains minnow, goldeye, and shovelnose sturgeon are also found in the Powder River and are collected much more frequently than sturgeon chub and western silvery minnow.

The sand shiner was first reported from the Yellowstone River basin in Wyoming in the 1960s by Baxter and Simon (1970). They report sand shiner in Ocean Lake, Clear Creek, and Teapot Creek in the Powder River headwaters. Sand shiner is considered native in the basin in Wyoming, but it is difficult to explain how this species, now clearly the most abundant species in lower elevation portions of the basin (Barrineau et al. 2007, Bear 2009, Peterson et al. 2009), was not collected during the previous 75 years of surveys. In his survey of streams and lakes in the Powder River drainage, Eiserman (1962) did not collect sand shiner, yet the species is considered native to the lower Yellowstone River in Montana (Holton and Johnson 1996). Patton (1997) documented the species in the Little Powder, Powder, Tongue and Bighorn/Wind drainages and determined that it was found at more sites, streams, and subdrainages than it had been in the 1960s. It is assumed that the sand shiner was likely native the Powder drainage in Wyoming where it was historically rare. If historically present elsewhere in the Yellowstone basin, it was very rare. The species has undoubtedly expanded in distribution and abundance in the Yellowstone basin and is now the most abundant species in the lower elevations.

In the early years of fishery management after 1950, most of the coldwater trout streams of the Yellowstone River basin in Wyoming were regularly stocked with multiple species of nonnative trout. Through the mid-1970s, non-indigenous fine spotted cutthroat from the Snake River drainage were stocked into many of the native Yellowstone cutthroat waters. In the 1970s, concern regarding the impacts of

stocking exotic trout on native populations had grown, and emphasis began to shift toward wild trout and native trout management.

The WGFD began raising Yellowstone cutthroat trout at the Clarks Fork Hatchery in 1977. South Paintrock Creek was the original, genetically pure, wild source of these fish (Messamer 1984). As Yellowstone cutthroat became available, stocking of some native cutthroat waters shifted from Snake River cutthroat to the native Yellowstone cutthroat trout (Kent 1975b). Stocking in the Shoshone River system above Buffalo Bill Dam has been limited solely to Yellowstone cutthroat since 1981, and the trout fishery above the dam is largely dependent upon natural reproduction of trout that ascend the North Fork Shoshone to spawn in tributary streams (Kent 1984, Kent 1995). Managers continue to emphasize wild trout management in streams wherever possible, and nonnative trout are now stocked only in waters outside of the historic range of the Yellowstone cutthroat trout and in waters where this stocking will not impact remaining conservation populations of native cutthroat in the Yellowstone River basin. Managers often use restricted bag limits and seasonal fishing closures to sustain wild Yellowstone cutthroat populations in areas with high fishing pressure. Managers have recently worked to identify remaining populations of genetically pure Yellowstone cutthroat trout, reduce trout losses to irrigation diversions, and to remove nonnative salmonids from some native cutthroat waters (See Conservation Initiatives below).

In the early 1990s, the Wyoming Game and Fish Department funded two research projects at the University of Wyoming that assessed the status of native fish populations in the Yellowstone River basin. One of these projects was a PhD project at the University of Wyoming, to survey warmwater stream fishes of the Missouri River drainage in Wyoming. This was the most detailed survey of Wyoming fishes that had been conducted prior to the 2005 Comprehensive Wildlife Conservation Strategy. Surveys conducted between 1992 and 1995 included 5 sites in the Little Powder, 24 sites in the Powder, 9 sites in the Tongue, 36 sites in the Bighorn/Wind, and 3 sites in the Clarks Fork drainages. Sites were focused in warmwater rivers and streams < 7,300 ft elevation (Patton 1997). Patton compared survey results to those from the 1960s and described trends in species occurrences across several spatial scales, including sites, streams, subdrainages, and drainages (Patton et al. 1995, Patton et al. 1998, Patton 2001). He also applied a number of metrics to determine the relative conservation value of various streams within the Yellowstone River basin for conservation of native fishes (Patton 2001).

The second project was conducted by a University of Wyoming master's student to assess populations of two fish SGCN, burbot and sauger, in lakes in the Bighorn/Wind River drainage (Krueger 1996). Simon (1951) reported that burbot were "common in the Bighorn River and some tributaries and was most abundant in the upper reaches of the Big Wind River. It is found also in the deep mountain lakes directly tributary to the upper waters of the Big Wind and a few specimens have been taken from the Tongue River." However, by the 1970s, small numbers of burbot were being captured during sampling in Ocean, Trail, Ring, and Torrey lakes, Pilot Butte Reservoir, and the Bighorn River below Boysen Reservoir (Facianni 1973, Kent 1977, Connell 1980, Connell 1982). Walleye were known to prey on burbot in Boysen Reservoir (Whaley et al. 1979), and angler harvest was sometimes high (Connell 1986). Although sauger were sampled routinely in Boysen Reservoir and were captured by anglers in the Bighorn River (Connell 1986), the status of both species was largely unknown. Krueger (1996) was the first project to attempt to evaluate the status of these two fishes in the Bighorn basin.

In the late 1990s, WGFD efforts to conserve sauger populations in the Bighorn/Wind River intensified. Welker conducted a multiple-year project to evaluate sauger habitat use in the Bighorn River (Welker et al. 2002). He determined that sauger habitat could be

improved by 1) manipulation of Boysen Reservoir discharge to more closely approximate the natural hydrograph, 2) manipulation of Yellowtail Reservoir storage, 3) fish passage through irrigation diversion dams, and 4) habitat structures that create low velocity, deep-pool habitat. Recommendations were also made to improve sauger spawning habitat in the river below Boysen Reservoir (Roberts et al. 2003).

The WGFD also funded a series of research projects at the University of Wyoming to assess sauger in the Wind River above Boysen Reservoir. Amadio (2003) assessed populations and habitat associations of sauger in the Wind River. Kuhn (2005) assessed movements of sauger in the Wind River and determined that sauger used large deep, low velocity pools throughout most of the year. Longer movements occurred during spring and early summer, and were associated with upstream and downstream migrations to and from spawning locations in the Little Wind River. After spawning, most sauger returned to locations where they had been tagged in the fall and spent the winter. Lionberger (2006) attempted to assess the locations of juvenile sauger nursery habitat in the Wind River watershed, but found no juvenile sauger in riverine habitat upstream from Boysen Reservoir. He found only four juvenile sauger in the reservoir; however, by assessing the chemical composition of otoliths of adult sauger he determined that Boysen Reservoir may be providing important nursery habitat for populations that reproduce in the river above the reservoir.

Recent native sportfish management efforts have not been limited to sauger and burbot. Kruse (1995, 1998) intensively studied three watersheds in the Absaroka Mountains of the Yellowstone River basin (Greybull River and North and South Forks of the Shoshone River) to describe remaining distributions of genetically pure Yellowstone cutthroat trout and to develop an understanding of factors governing distribution and genetic structure necessary for future conservation efforts. He determined that only 26% of the 104 streams containing trout still support genetically pure native cutthroat, indicating a 70% loss in native trout from their historic distribution within these watersheds. In 1998, Yellowstone cutthroat trout were petitioned for listing as a threatened species under the Endangered Species Act (ESA). The U.S. Fish and Wildlife service rejected the petition in 2001, but in December 2004, the U.S. District Court for the District of Colorado ruled that the U.S. Fish and Wildlife Service (USFWS) had illegally rejected the petition. The USFWS conducted a 12-month status review of the species and found listing unwarranted.

Comprehensive surveys documenting the occurrence of Yellowstone cutthroat trout in their historic range in the upper Little Bighorn and Tongue River drainages were also conducted (Bradshaw et al. 2008). Results from these 1999–2001 surveys were used to refine estimates of historical Yellowstone cutthroat trout distribution, identify current distribution of the subspecies, assess genetic purity, determine the distribution of introduced salmonids, identify potential barriers to fish passage within the two drainages, and describe the habitat in both drainages. Six genetically pure populations were identified, including populations in Red Gulch Creek (Little Bighorn River drainage) and the South Fork of the Little Tongue River (Tongue River drainage) that were previously unknown. Information from these surveys was incorporated into the most recent range-wide Yellowstone cutthroat trout status assessment (May et al. 2007). Drainages were prioritized for local conservation and population expansion efforts, based on the vulnerability of existing populations and their habitats, and consistent with the interstate Memorandum of Understanding for Yellowstone cutthroat trout management across the West (MOU 2000). An updated agreement, including conservation strategies for this species was completed in 2009 (Range-wide YCT Conservation Team (2009).Like the other Wyoming basins in the Missouri River drainage (Platte and Northeast Missouri), the Yellowstone River basin has a diverse assemblage of native species and introduced

species. The native sportfish community remains intact, but five of the seven native sportfish are considered SGCN (table 12) and are actively managed by the WGFD. Portions of the Yellowstone River basin contain Wyoming's last populations of sauger and shovelnose sturgeon and a unique assemblage of nongame species adapted to large, turbid rivers.

**Aquatic Reptiles**

Three turtles are found in the Yellowstone River basin, all of which are considered native species. The western spiny softshell and western painted turtle are SGCN, but the eastern snapping turtle is not. The western spiny softshell is known from the Little Powder, Powder, Tongue, Nowood and Bighorn Rivers. The western painted turtle is found in all of the major subdrainages in the Yellowstone River basin and is probably most common in Clear and Crazy Woman Creeks in the Powder River drainage. It is the only turtle species known from the Clarks Fork of the Yellowstone River in Wyoming. The eastern snapping turtle is found in the Little Powder, Powder, Tongue, Little Bighorn, and Bighorn River drainages. The species has only been found in the downstream portions of the Little Bighorn and Bighorn River drainages, near the Montana state line.

Baseline survey data are needed for all turtles in the Yellowstone River basin.

**Freshwater Mollusks and Crayfishes**

Wyoming is still in the discovery phase in terms of its freshwater bivalve mollusks and gastropods. Although fingernail and pill clams and aquatic gastropods are often encountered during invertebrate sampling, few published accounts of mollusk collections exist (Beetle 1989, Henderson 1924, Hoke 1979, Hovingh 2004). Native mussels, clams, and gastropods are thought to be present in every major Wyoming drainage, except the Green River and Great Divide basins where no bivalve mussels (Order Schizodonta) have been documented. All native mussels, clams, and gastropods are considered SGCN by the WGFD due to a lack of information regarding status.

As of early 2010, seven species of native mussels were known to inhabit Wyoming waters, two of which have been documented in the Yellowstone River basin. The fatmucket *Lampsilis siliquoidea* is the most widespread native mussel in the basin, and many populations are known. Nine of the 21 fatmucket collections were live. Living populations are spread throughout the Powder, Tongue, and Bighorn/Wind river drainages. The giant floater *Pyganodon grandis* was recently discovered in the Little Powder drainage near the Montana state line. It is only known from one other location in the Yellowstone River drainage in Montana. Researchers from Montana State University recently documented the western pearlshell *Margaritifera falcata* in the Madison and Little Firehole rivers in Yellowstone National Park (YNP). However, waters that do not extend outside the boundaries of YNP and into Wyoming are not included in the Yellowstone basin of the SWAP.

One biologist position on the Wyoming Game and Fish Department Aquatic Assessment Crew has been assigned to coordinate mollusk sampling and collect observations. Field personnel have been trained to record bivalve mollusk observations during other routine fieldwork and submit specimens. A voucher specimen collection was established at the University of Colorado Natural History Museum in Boulder, Colorado, in 2007.

The exotic New Zealand mudsnail is established within the Yellowstone River basin, but the distribution is not well known. The species has been documented in portions of the Bighorn River near Thermopolis and the Shoshone River downstream of Cody.

In 2009, the WGFD funded a project at the University of Wyoming to conduct a literature review, identifying the current and historical information on freshwater gastropod distributions in Wyoming and to develop gastropod collection methods for WGFD, and assess the distribution of freshwater gastropods

in the Bighorn and North Platte River drainages in Wyoming. Researchers attempted to sample four sites in every 8-digit HUC basin. Data suggest that sampling techniques often employed for macroinvertebrates do not accurately reflect the occurrence of snails. Sampling protocols for freshwater gastropods will also be developed as part of this research project.

Researchers surveyed sites throughout the Bighorn River basin and classified six types of mesohabitats. Run, riffle, pool, and backwater were used to describe discrete habitats in streams and rivers. Mainstem was used to indicate sites where the margin of the mainstem Bighorn River was sampled. Finally, littoral was used to describe habitat in the littoral zone of standing waters. Distributions of gastropods and habitat associations will be provided in the M.S. thesis (Charlotte Narr) for this project in winter 2010–11, and current distributions will be compared to those derived from observations reported by Beetle (1989).

Little information is available on the distribution of Wyoming crayfishes. All native crayfishes are considered SGCN. Between 1985 and 1987 a survey of crayfishes was conducted in Wyoming (Hubert 1988). These surveys were repeated between 2007 and 2009 (Hubert 2010). Two species, both of which are native, were documented in nine waters in the Yellowstone River basin in the first survey: *Orconectes immunis and O. virilis*. *O. immunis* was the most common with *O. virilis* found only in Todd Reservoir in the Powder River drainage and the Popo Agie River in the Bighorn River watershed (Hubert 1988). In the 2007–2009 survey, crayfish were sampled from 15 waters in the Yellowstone River basin. *O. virilis* was the only species found at eight of these sites, and *O. immunis* was the only species at the other seven sites. *O. immunis* appears to have been displaced by *O. virilis*, a native, but highly invasive species, at a number of locations in Wyoming, including Boysen Reservoir and Maverick Pond in the Yellowstone River basin. More detailed surveys are needed to describe the distribution and status of crayfishes in Wyoming.

**Table 12. Species of Greatest Conservation Need present in the Yellowstone River Basin**

***Fish***
Brassy minnow
Burbot
Flathead chub
Goldeye
Mountain whitefish
Plains minnow
Sauger
Shovelnose sturgeon
Sturgeon chub
Western silvery minnow
Yellowstone cutthroat

***Aquatic Reptiles***
Western painted turtle
Western spiny softshell

***Crustaceans***
Calico crayfish

***Mollusks***
Fatmucket mussel
Giant floater mussel

## Identification of Conservation Areas

In order to address needs of the diverse fish assemblage of the Yellowstone River basin, conservation areas include wide-ranging habitats from mountain lakes, coldwater streams, warmwater streams, and large rivers (Figure 12).

The Powder River basin in Wyoming contains a unique assemblage of fishes adapted to river habitat with relatively unstable substrate and high turbidity. This assemblage includes the shovelnose sturgeon, plains minnow, western silvery minnow, sturgeon chub, flathead chub, sauger, and goldeye. Many of these species migrate long distances to spawn. The Powder River is one of the last free-flowing prairie streams in the entire Missouri River basin. The conservation area includes the mainstem Powder River downstream of Kaycee, Wyoming, Clear Creek below Hwy 14/16, Crazy Woman Creek below Interstate 90, and the

Little Powder River below the confluence of Cottonwood Creek.

The lower Nowood River, below Big Trails, Wyoming, is an important conservation area for native nongame species in the Bighorn River drainage. It is home to a diverse assemblage of fishes, including many SGCN (Bear 2009).

Priority areas for the conservation of native Yellowstone cutthroat are numerous and widespread. On the north and east slopes of the Bighorn Mountains, these include Lodgegrass Creek (HUC 100800160301), the West Fork Little Bighorn River (HUC 100800160104), Elkhorn Creek and Red Gulch creeks (HUC 100800160103), the North and South forks of West Pass Creek (HUC 100800160107) in the Little Bighorn drainage, and the South Fork Little Tongue River (HUC 100901010107).

In the Wind/Bighorn River drainage on the west side of the Bighorn Mountains, priorities include the North Fork Shoshone River drainage above Buffalo Bill Reservoir (HUCs 1008001201, 1008001202, and 1008001203),

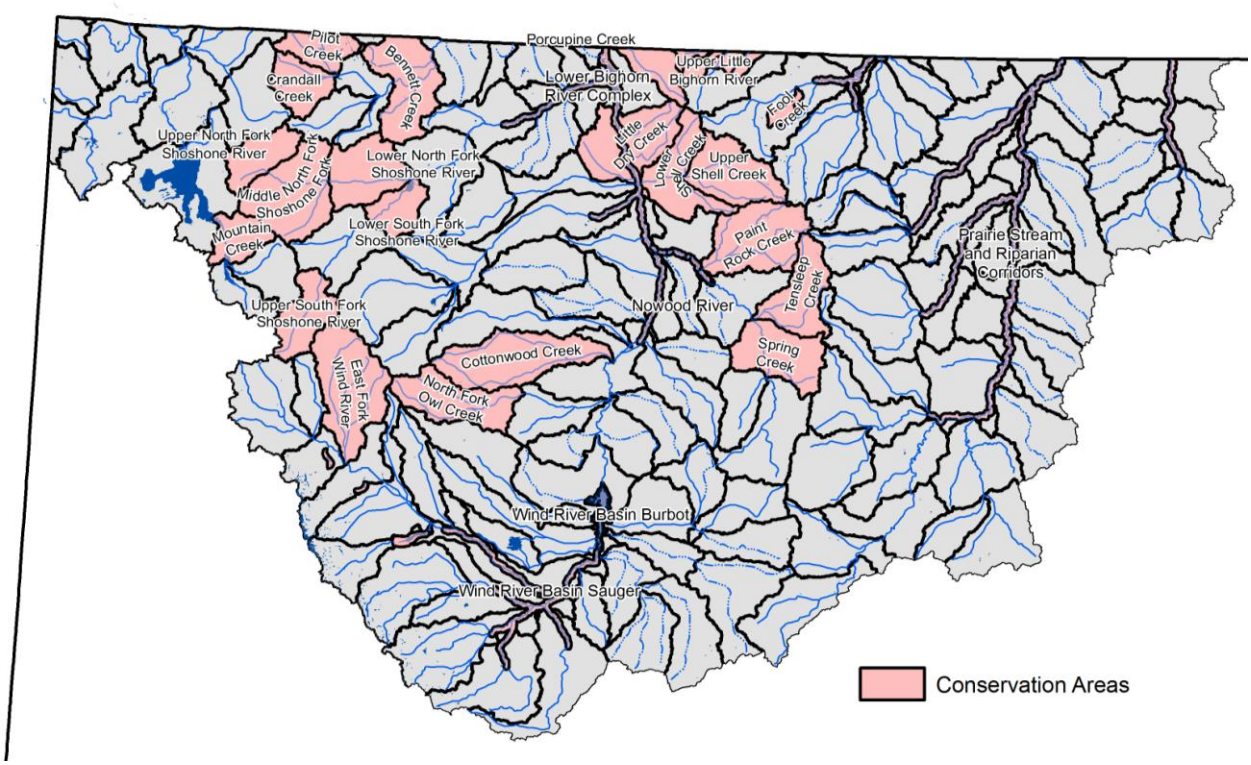


**Figure 12. Aquatic Wildlife Conservation Areas in the Yellowstone River Basin.**

Cottonwood Creek HUC 1008000706), South Fork Owl Creek (HUC 1008000702), Upper South Fork of the Shoshone River (HUC 1008001301), Ishawooa Creek (HUC 1008001302), Marquette Creek (HUC 1008001303), Greybull and Wood River drainages (HUC 10080009), Trout Creek and Deer Creek (HUC 1008001006), Bear Creek, (HUC 1008001000), North and South Beaver Creeks (HUC 1008001002), Cedar Creek (HUC 1008001001), Mill Creek, Dry Medicine Lodge Creek, and South Paintrock Creek (HUC 1008000806), East Tensleep Creek (HUC 1008000804), South Fork of Otter Creek (HUC 1008000803), and the East Fork Wind River (HUC 1008000104).

In the upper Yellowstone River drainage priorities include the Yellowstone River headwaters (HUC 10070001) and tributaries (HUC 1007000103), Crandall Creek and

tributaries (1007000602), Muddy Creek (1007000601), Littlerock Creek and Deep Lake (1007000605).

In order to conserve sauger in the Bighorn/Wind River drainage, the following areas have been identified below Boysen Dam: Big Horn Lake and the Bighorn River below the Lower Hanover Diversion south of Worland, the Shoshone River below Penrose Dam, and the Greybull River below the Highway 30 Bridge. Priorities above Boysen Dam are Boysen Reservoir to the upper extents of sauger distribution. This includes the Wind River up to Diversion Dam, Popo Agie River up to confluence with North Fork Popo Agie River, Little Popo Agie River up to confluence with Willow Creek, and Little Wind River up to Sub-Agency Ditch Diversion.

In order to conserve burbot in the Bighorn/Wind River drainage, the following areas have been identified: Bull Lake, Lower and Upper Dinwoody lakes, Torrey, Ring, and Trail lakes on Torrey Creek, Boysen Reservoir, Bighorn River and Big Horn Lake.

Priority drainages and habitats have not yet been defined for the conservation of aquatic reptiles, freshwater mollusks, or crayfishes.

## Threats

**Water development/altered flow regimes – Moderate**

Natural flow regimes in stream segments around the state have been altered by human activities, including irrigation diversions and water developments for more reliable water supply, hydropower, and flood control. These 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). Lateral and longitudinal hydrologic connectivity and physical access by fish populations to all habitats necessary to complete their life history is limited throughout the drainage. In-channel obstructions and increased dewatering have reduced some populations of native stream fishes.

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. This trend has multi-faceted consequences for fish and wildlife and the habitats upon which they depend. In Wyoming, trans-basin water diversions are not uncommon and are likely to be further proposed and pursued. 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 alter the timing, magnitude, and duration of natural hydrographs and reduce intra- and inter-annual variability in Wyoming's streams and associated riparian corridors (see Wyoming Leading Wildlife Conservation Challenges – Climate Change, and the Riparian habitat chapter).

While water development can threaten native species, some introduced species, including those in 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 fishery in Boysen Reservoir depends on the consistent deep water and forage production inherent in this manmade water body. Stable stream flow releases from dams, with relatively low peak flows and relatively high base flows, perpetuate productive sport fisheries like that below

Boysen and in the lower Shoshone River below Buffalo Bill Reservoir.

**Drought and climate change – Moderate**
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).

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). Drought lowers water tables, leading to reduced plant growth and reproduction. Riparian vegetation declines lead to lower bank stability, higher siltation and altered stream habitat quality and quantity. Lower water levels increase water temperatures and reduce the habitat available to fish and other aquatic wildlife. All these conditions can be detrimental to the health and reproductive success of all aquatic wildlife species.

**Invasive species – Moderate**
The primary threats from invasive species in the Yellowstone River watershed are from hybridization with rainbow trout or other cutthroat subspecies.

Aquatic invasive species (AIS) including fish, pathogens, plants, and mollusks are currently present in Wyoming, most notably the New Zealand mudsnail and the parasite that causes whirling disease. These AIS can alter the native species in a watershed through competition, disease, shifts in food availability, and direct mortality. While AIS currently in Wyoming can cause problems and need to be controlled, the most significant known threat to Wyoming's native species is from zebra and quagga mussels, based on their proximity to Wyoming and demonstrated negative impacts in other areas. Zebra and quagga mussels can out-compete native mussels for space and resources and will attach to and smother native mussels causing mortality (Cummings and Mayer 1992, Strayer 2008). They filter plankton out of the water column at high rates (up to a liter per day per individual) so that little plankton remains available for fish populations, resulting in their decline (Benson 2009). In addition, invasive mussels produce pseudofeces which can lead to harmful algal blooms affecting numerous aquatic species.

The Wyoming Aquatic Invasive Species Act of 2010 allowed the WGFD to implement the Wyoming AIS Program with the goal of executing a coordinated strategy to prevent, control, contain, monitor, and whenever possible, eradicate aquatic invasive species from the waters of the state. The Wyoming AIS Management Plan of 2010 is the framework for this three-part strategy which includes 1) outreach and education, 2) inspection of watercraft to increase boater awareness of AIS threats and prevention and to intercept high risk watercraft that may be transporting AIS, and 3) monitoring of waters to allow for early detection and rapid response to any new AIS populations in the state.

## Conservation Initiatives

Numerous projects have been completed to benefit SGCN in the Yellowstone River basin since the implementation of the 2005 Comprehensive Wildlife Conservation Strategy. Multiple sources of funding have been used to fund projects with partners at local universities. Other projects have been conducted by department personnel. Although this list is not complete, many of the significant initiatives are summarized below in chronological order.

Since construction of Boysen Dam, the main channel of the Bighorn River has been incised causing the loss of several habitat features important to fish. Losses of these habitat features have probably contributed to changes in fish assemblages within the Bighorn River. The WGFD funded a research project at the University of Wyoming to assess changes in habitat. Wilhite (2007) used color infrared aerial photographs as a tool to monitor habitat features in rivers needed by native fish. Several

habitat features were identifiable in the photographs including backwaters, side channels, sand bars, riffles, and main channels. This information will be used to help managers improve habitat conditions for SGCN in the river below Boysen Reservoir.

WGFD biologists conducted a systematic inventory of streams in the upper Yellowstone River watershed to determine Yellowstone cutthroat trout abundance, distribution and habitat conditions within the watershed (Burckhardt 2009). Yellowstone cutthroat trout were the only fish species sampled and were found to occupy approximately 126 stream miles in the upper Yellowstone watershed within Teton Wilderness, Bridger-Teton National Forest. Juvenile cutthroat trout were captured throughout most of the drainage, but adults were rare outside of the spawning season. The apparent reduction in trout populations in the upper Yellowstone River was attributed to a combination of factors, including whirling disease, lake trout predation in Yellowstone Lake, and an extended period of drought.

The WGFD funded a research project at the University of Wyoming to assess burbot populations in eight lakes and reservoirs of the Wind River drainage known to support the species. Abrahamse (2008) described characteristics of burbot populations in Boysen Reservoir, Torrey Lake, Bull Lake, Lower Dinwoody Lake, Upper Dinwoody Lake, Trail Lake, Ring Lake, and Ocean Lake. He determined that a better understanding of the effects of environmental and human factors on burbot populations is needed to manage burbot fisheries effectively.

The WGFD conducted a SWG-funded project in 2004 and 2005 to assess the distribution and status of fishes in eastern Wyoming prairie streams. It had been 10 years since Patton's surveys were conducted in eastern Wyoming (Patton 1997). One of the project objectives was to utilize the newly developed Warmwater Stream Assessment (WSA) protocol (Quist et al. 2004) to assess habitat conditions and fish communities. This effort included surveys at three sites in the Little Powder River (Barrineau et al. 2007) in the Yellowstone River basin. Results were used to begin prioritizing eastern prairie streams for native species conservation (Bear 2006) (See Identification of Conservation Areas above). The Little Powder River was determined to have high conservation value for fish SGCN.

During the past decade, the Powder River basin in Wyoming and Montana has been undergoing the world's largest development of coalbed natural gas (CBNG) extraction. Potential exists for substantial effects on aquatic ecosystems because CBNG development involves production and disposal of large quantities of CBNG product water that differs from surface waters and alters natural flow regimes (Davis 2008). Multiple projects were conducted to assess potential impacts. WGFD biologists conducted detailed fish and habitat surveys at multiple sites in the Powder River and lower Crazy Woman Creek from 2004–2006. This project described the fish community and habitat at multiple sites, monitored spatial and temporal shifts in community, structure and aquatic habitat, described habitat associations of individual species, and monitored stream discharge and geomorphology in established reference reaches (Peterson et al. 2009, WGFD 2004, WGFD 2005, WGFD 2006). A second project, conducted by Montana State University researchers in 2005 and 2006 compared fish assemblages in streams with (treatment) and without (control) CBNG development, determined fish presence, growth, and survival in streams composed entirely of product water, and compared fish assemblages at multiple points above and below development to determine the effects of coal-bed natural gas development on fish assemblages in the Powder River basin (Davis 2008). The third project was a survey of reptiles and amphibians in the Powder River basin from 2004–2006, concentrating on riparian areas of the Powder River and tributaries. This project was also initiated to collect baseline information needed to assess impacts of the burgeoning coalbed methane development in the basin. Surveys were conducted in May, June, July, and August

each year. All three species of turtles known from the basin were collected (Turner 2007).

The WGFD also conducted a SWG-funded project in 2006 and 2007 to assess aquatic habitat conditions and describe fish communities in warmwater stream systems in the Bighorn River drainage. Surveys were conducted at 102 sites in the Greybull, Nowood, Shoshone, and Bighorn River watersheds. Sixteen native species were sampled, including 11 currently listed as SGCN. The lower Nowood River was identified as an important conservation area for native fish species (Bear 2009). Concurrent with this project, WGFD biologists conducted a study to assess movements of native large-bodied fishes in the Bighorn River and a major tributary, the Greybull River. Passive integrated transponder tags were used to assess movements of multiple species. Shorthead redhorse, sauger, channel catfish and river carpsucker all utilized the Greybull River during the study (Smith 2008a). Use of the lower Greybull River by most species was short-term and appeared related to spawning, but use by sauger was generally of longer duration and primarily by juveniles.

WGFD biologists have recently conducted multiple assessments to describe and quantify fish entrainment in diversion canals in the Bighorn River drainage. Water passing through canals was sampled with a fine mesh net. Entrainment of all species, including multiple fish SGCN, was estimated. During the 2006 and 2007 irrigation seasons, entrainment studies were conducted on Harmony Ditch, the low elevation irrigation diversion on the Nowood River (Smith 2008b) and the Cody Canal, the lowest irrigation diversion on the South Fork Shoshone River (Smith 2008c). Fish entrainment in the Cody Canal may be suppressing trout populations in the South Fork Shoshone River. Fish entrainment was also assessed in the North Fork Ditch, the largest irrigation diversion on the North Fork Shoshone River during the 2008 irrigation to determine the potential benefit of applying a fish screening device (Smith 2009). The rate of entrainment for all species was low compared to other diversions in the region and was determined to have relatively little impact on the North Fork Shoshone River fishery.

Fish passage and screening projects have increasingly been implemented with the development of a WGFD fish passage program in the last few years and an active Trout Unlimited organization. For example, screens were installed in 2007–2009 on three diversions from Trout Creek, an important spawning and nursery stream for Yellowstone cutthroat trout in the North Fork Shoshone River drainage. Likewise, extensive fish loss investigations in major diversions in the South Fork Shoshone River drainage and Nowood River drainage were conducted to prioritize diversions for screening. Plans are actively being pursued to improve passage for a diverse fish community that includes SGCN at a diversion from the Nowood River. Similarly, a culvert barrier to Yellowstone cutthroat trout movement on Francs Fork Creek was replaced with a bridge in 2009. An irrigation diversion on Bear Creek, in the East Fork Wind River drainage, is being replaced in 2010 and will include a fish screen to prevent entrainment of Yellowstone cutthroat trout. Numerous improvements to diversions and barriers east of the Bighorn Mountains, particularly in the Tongue River and Clear Creek, will benefit native fish communities. Further examples and details are elaborated in WGFD annual strategic habitat plan reports (e.g., WGFD 2010).

In 2009, funding provided by the Wyoming Governor's office was used to fund a project through the University of Wyoming to begin assessing the status of aquatic gastropods in Wyoming. The project was conducted by Charlotte Narr, a University of Wyoming master's student, under the supervision of Dr. Amy Krist. Project objectives are to conduct a thorough literature review to determine the historical distributions of aquatic gastropods in Wyoming, develop appropriate sampling protocols for freshwater gastropods and their aquatic habitats, and to conduct extensive sampling in the North Platte and Bighorn River

drainages. A thesis will be completed during the winter of 2010–2011.

The Kendrick Dam is an irrigation dam about five miles upstream of the confluence of Clear Creek on the Powder River. The dam has blocked all upstream fish movement for over 100 years. Channel catfish, sauger, shovelnose sturgeon, goldeye, northern redhorse, and river carpsucker are prevented from migrating upstream. However, after many years of effort by the WGFD, a fish bypass channel was constructed in the winter of 2009–2010 and became operational in the spring of 2010 opening about 36 stream miles of this tributary to migrant fishes. Completion of this project was a milestone in the department's efforts to conserve fish SGCN in the Powder River basin.

The WGFD has been actively working to restore Yellowstone cutthroat trout in priority sub-drainages within the Yellowstone basin. Genetic purity of native cutthroat populations was assessed by Pisces Molecular, LLC (Boulder, CO), using the amplified fragment-length polymorphism (AFLP) technique. Diversity within populations of cutthroat and relatedness between populations was also assessed. Genetically pure Yellowstone cutthroat populations were confirmed in the Little Bighorn drainage (Lodgegrass, Elkhorn, Red Gulch, South Fork West Pass, and Pumpkin Creeks), Tongue River drainage (South Fork Little Tongue River), the Wind River headwaters (Bug Creek, upper Wiggins Fork and Caldwell Creek), the Shell Creek drainage (Trapper, Cedar, North and South Beaver Creeks), the Porcupine Creek drainage (Trout and Deer Creeks), and in the Nowood River drainage (Paintrock and South Paintrock Creeks). Evidence of slight rainbow trout admixture (<5%) was seen in Yellowstone River cutthroat in Bear Creek, the North Fork Shoshone River, and the Wiggins Fork at Black Mountain.

Chemical rehabilitation projects to remove nonnative salmonids and secure native cutthroat populations were completed on many streams in the Bighorn Mountains. On the north and east slopes of the Bighorns, rehabilitation projects were completed on 1.2 miles of Elkhorn Creek and 1.0 miles of Red Gulch Creek. Fifteen miles of the Little Tongue River and three main tributaries were treated in 2009 and 2010. Preparation was begun for treating the lower Little Tongue River below Fallen City and the lower South Little Tongue River. On the west slope of the Bighorns, 3.3 miles of Dry Medicine Lodge Creek were treated in 2006 and 2007. In 2008 and 2009 7.4 miles of Buckskin Ed and in 2010 about 12 miles of Soldier Creeks (South Paintrock Creek tributaries) were treated. In 2009 and 2010, nine miles of Dead Indian Creek in the Clarks Fork drainage was also chemically treated to restore native cutthroat.

Wyoming Game and Fish Department studies of relationships between stream flow and habitat for Yellowstone cutthroat trout have occurred throughout the Yellowstone basin in Wyoming. From these studies, 27 instream flow water rights have been filed by the WGFD and Wyoming Water Development Office and permits were approved by the State Engineer. These instream flow water rights permits protect 108 miles of streams in the Greybull River, Upper Wind River, Shoshone River, and other drainages (Paul Dey, personal communication).

The WGFD's Fish Division has developed basin management plans to guide management across the state. These plans provide background and history of aquatic wildlife management as well as management direction for sportfish, SGCN, and aquatic habitat. The management direction includes reference to the SWAP and the Strategic Habitat Plan, attempting to incorporate management direction from those two plans that is relevant to each basin into each basin management plan.

The WGFD has the opportunity to comment on most environmentally sensitive construction or management actions submitted through the National Environmental Policy Act (NEPA) review process. Projects include state and federal lands and private ventures that require action by county, state or federal agencies. The WGFD regularly provides recommendations to protect habitat and populations of aquatic

wildlife at the project level. Department efforts are guided by Wyoming Game and Fish Commission mitigation policy (Wyoming Game and Fish Commission 2008).

The WGFD has a rigorous collection permitting system that restricts commercial, scientific, and educational activities (Wyoming Game and Fish Commission 2005a). It provides protection to aquatic wildlife. The regional fisheries supervisor reviews all requests for permits and recommends either approval or rejection of the request based on merit and impacts to the resource in question.

The movement of fish by WGFD employees is critical to address many of the aspects, thus the intent, of our mission. However, the act of moving or importing fish also presents risks that could potentially jeopardize that mission. To address this conflict, a method to determine the relative level of risk associated with any proposed fish importation and/or transplant was developed. The WGFD utilizes Hazard Analysis and Critical Control Point (HACCP) procedures (Gunderson and Kinnunen 2001) and has developed a Risk Assessment Matrix from these procedures to manage transplants, thereby protecting the aquatic resources within the state. Using the procedures and matrix, WGFD fisheries managers develop documentation that explains whether a transplant is nearly free of risk. The documentation must address all aspects of the transplant including, but not limited to, verifying that the fish being transplanted are disease free, the water source is disease free, and non-target species are excluded from transplant. Source populations of salmonids are verified disease free by collecting a standardized number of fish, having them inspected by an American Fisheries Society-certified Fish Health Inspector for all known pathogens, and receiving disease free certification. The resulting documentation is reviewed and either approved or denied by the WGFD Chief of Fisheries. No whirling disease-infected trout, native or nonnative, are stocked by the WGFD, and they are not allowed to be stocked by others (Wyoming Game and Fish Commission 2003).

In Wyoming, state Game and Fish Commission policy precludes the stocking of fish into waters that are capable of satisfactory, self-sustaining fisheries (Wyoming Game and Fish Commission 1998). A commonsense, biologically based protocol for fish rearing and stocking has historically been followed in Wyoming, with emphasis on management for native fish and wild fish wherever possible (Wiley 1995). Only 3% of the streams listed in the Wyoming Game and Fish Department database inventory are stocked annually. Maintenance of native cutthroat trout subspecies has been a management priority for more than 40 years (Stone 1995), and protection from stocked predators of native nongame fishes has been an important consideration for at least the last decade.

Wyoming has regulations prohibiting unauthorized stocking of fish or fish eggs. Private citizens can only stock waters in Wyoming following a WGFD permitting system that includes review by the responsible regional fisheries supervisor (WGFD 2005b). The WGFD has increased education efforts regarding the problems associated with illegal introductions of fish. The Wyoming Legislature increased the penalties for illegal fish stocking in 2010, and the Wyoming Wildlife Protectors Association has offered $2,500 rewards for information leading to the conviction of individuals found illegally moving or stocking fish.

Habitat management efforts are guided by the Strategic Habitat Plan (SHP) that was adopted by the Wyoming Game and Fish Commission in January 2009. The SHP includes five goals: 1) Conserve and manage wildlife habitats that are crucial for maintaining terrestrial and aquatic wildlife populations for the present and future, 2) Enhance, improve, and manage priority wildlife habitats that have been degraded, 3) Increase wildlife-based recreation through habitat enhancements that maintain or increase productivity of wildlife, 4) Increase public awareness of wildlife habitat issues and the critical connection between healthy habitat and abundant wildlife populations, and 5) Promote

collaborative habitat management efforts with the general public, conservation partners, private landowners, and land management agencies. Efforts are focused in priority areas in each of the management regions and include crucial areas essential for conservation of important species and communities and enhancement areas, which represent places where work should be conducted to manage or improve wildlife habitat.

The Wyoming Legislature created the Wyoming Wildlife and Natural Resource Trust (WWNRT) in 2005. Funded by donations, legislative appropriation, and interest earned on a permanent account, the purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. Any project designed to improve wildlife habitat or natural resource values is eligible for funding. The WWNRT is an independent state agency governed by a nine-member citizen board appointed by the Governor. The WGFD has partnered with the WWNRT to successfully implement a wide range of projects to benefit a broad array of Wyoming's wildlife.

Landscape Conservation Cooperatives (LCCs) are a new program of the U.S. Fish and Wildlife Service. The vision is that they serve as applied conservation science partnerships focused on a defined geographic area that inform on-the-ground strategic conservation efforts at landscape scales. LCC partners include U.S. Department of Interior agencies, other federal agencies, states, tribes, non-governmental organizations, universities, and others stakeholders. It is hoped that LCCs will enable resource management agencies and organizations to collaborate in an integrated fashion within and across landscapes. LCCs are intended to provide scientific and technical support to inform landscape-scale conservation using adaptive management principles. They are proposed to engage in biological planning, conservation design, inventory and monitoring program design, and other types of conservation-based scientific research, planning, and coordination. It is hoped that LCCs will play an important role in helping partners establish common goals and priorities, so they can be more efficient and effective in targeting the right science in the right places. Products developed by LCCs should inform the actions of partners and other interested parties in their delivery of on-the-ground conservation. The WGFD will continue to participate in the LCC process as appropriate.

The states of Idaho, Montana, Nevada, Utah, and Wyoming, along with the U.S. Forest Service and Grand Teton and Yellowstone National Parks, signed a Memorandum of Agreement to jointly conserve, protect, and restore Yellowstone cutthroat trout populations within their historic range (Range-wide YCT Conservation Team 2009). This agreement has significantly advanced range-wide conservation and management efforts. The most notable accomplishment of the Yellowstone Cutthroat Trout Interstate Workgroup, working under the auspices of the 2000 Memorandum of Agreement (MOA), is the completion of a range-wide status assessment (May et al. 2003, 2007). The status assessment used the best scientific information available, and a strict decision-making protocol was conducted by teams of experts with the best information and background to perform the assessment. This effort produced the best estimate of current and historic range ever developed. This assessment is updated annually with the most recent published in 2007 to include recent genetic and sampling information (May et. al 2007). This interagency range-wide group is also operating under a new MOA and has developed a conservation strategy to guide future YCT conservation efforts (Region-wide YCT Conservation Team 2009).

The National Fish Habitat Action Plan (NFHAP) was developed by a coalition of fisheries professionals, state and federal agencies, tribes, foundations, conservation and angling groups, businesses and industries, all determined to reverse the declines of America's fish habitats. In its design, the plan encompasses five important lessons that emerge from America's past efforts to protect and restore fish habitat: 1) Be strategic rather than

merely opportunistic, 2) Address the causes of and processes behind fish habitat decline, rather than the symptoms, 3) Provide increased and sustained investment to allow for long-term success, 4) Monitor and be accountable for scientifically sound and measurable results; and, 5) Share information and knowledge at all levels from local communities to Congress. The Wyoming Game and Fish Department has been heavily involved with the development and implementation of the NFHAP. The WGFD is involved with three NFHAP partnerships, Great Plains Fish Habitat Partnership, the Western Native Trout Initiative, and the Desert Fishes Habitat Partnership. The first two cover the Yellowstone River Basin.

The mission of the Western Native Trout Initiative (WNTI) is: "To serve as a key catalyst for the implementation of conservation or management actions, through partnerships and cooperative efforts, resulting in improved species status, improved aquatic habitats, and improved recreational opportunities for native trout anglers across western states." Their vision is: "An increase in healthy, fishable western native trout populations resulting from sharper focus and commitment to action on common conservation needs of western native trout; enhanced public benefit resulting from multiple partners working together, sharing resources, and speaking with a united voice about the conservation and value of western native trout; and increased funding to accomplish strategic actions as a result of greater community and financial support from initiative partners and collaborators." By working together, the partners in WNTI are striving to implement the most strategic actions needed to benefit these trout. And by working together to establish secure populations, WNTI will also benefit anglers by enhancing recreational fishing opportunities for unique trout species across the West.

The Great Plains Fish Habitat Partnership is a coalition of interests concerned for the future of the rivers and streams of the "Great Plains" of the north central United States and the species that rely on these unique habitats. The Partnership is comprised of individuals, groups, and organizations that recognize the values of these aquatic habitats to fish and aquatic species, communities, and people that call this area home. The goal of the partnership is to work together to conserve (protect, restore, and enhance) aquatic resources of rivers and streams throughout the prairies of the central United States. This partnership will focus on the conservation of remaining high-quality prairie rivers and streams, the restoration of highly degraded habitats, where feasible, and the enhancement of habitats that have been moderately impaired. Wyoming is an active participant in the Great Plains Fish Habitat Partnership.

## Recommended Conservation Actions

**Secure and enhance populations and habitats in SGCN priority areas.**
Evaluate the feasibility of reducing populations of or removing nonnative fishes from priority conservation areas in the basin.

Complete chemical rehabilitation projects to restore Yellowstone cutthroat within the species' native range. Complete scheduled projects in the Little Tongue River drainage in 2010–2011 and the upper Paintrock Drainage (Soldier Creek) in 2011-2012.

Survey streams above natural barriers in the basin to determine their potential for establishing Yellowstone cutthroat refugia.

Provide fish passage and reduce entrainment at Nowood River irrigation diversions.

Develop a sauger spawning operation on the Bighorn River that will provide a path for the state of Montana to discontinue stocking of potential walleye-sauger hybrids in Big Horn Lake.

**Complete status assessments of native species in the basin.**

Determine the status, distribution, and habitat associations of turtles, mollusks, and crayfishes in the Yellowstone River basin.

Determine if goldeye, plains minnow, western silvery minnow, and sturgeon chub persist in the Bighorn River and document associated habitats.

Determine basic biology, life history, and habitat requirements of shovelnose sturgeon, goldeye, sturgeon chub, plains minnow, western silvery minnow, sauger, and flathead chub and implement actions to conserve these species in the basin.

Continue efforts to identify factors limiting sauger and burbot populations within the Wind River drainage.

**Continue aquatic habitat work in the basin.**
Initiate discussions with irrigators to obtain fish passage past the next barrier upstream from Kendrick Dam in Clear Creek.

Continue coordinating with the NRCS and landowners, and nongovernmental organizations to address fish losses into irrigation diversions in priority watersheds.

Evaluate potential and develop projects to reconnect oxbows, side channels, and backwaters.

Supply flow and other information to the State Engineer's Office and Water Development Office to facilitate adjudication of instream flow water rights.

Monitor instream flow segments for compliance with approved instream flow levels. Pursue compliance as needed when water is available and in priority.

**Explore water management approaches that enhance fish habitat.**
Work with water managers and landowners to improve low flow conditions through improved water management and more efficient irrigation systems (seal canals, surge valves, sprinklers, etc.,) to maintain river habitat, streamside vegetation, and fisheries.

Identify stream segments where habitat and available flow regimes indicate a need to file instream flow water rights for SGCN. As opportunities are identified, conduct needed studies and file for state-held instream flow water rights.

Identify fish and wildlife mitigation for new reservoirs as they are proposed including instream flow regimes and minimum fishery pools. Ensure that mitigation recommendations are included as conditions in applicable permits.

**Increase educational efforts about the ecological, economic, and social values of aquatic SGCN.**
The importance and role of aquatic SGCN is poorly understood by the public. Efforts should be enhanced to increase public education in this area.

**Continue building voucher collections for all aquatic wildlife.**
Continue to fill voids in voucher inventory for fish per WGFD protocol (Zafft and Bear 2009).

Mussel specimens have been donated to the University of Colorado Museum, and new specimens will be added as needed. A database containing freshwater mussel occurrences will be maintained and enhanced with specimen photos.

Determine if there is interest in voucher specimens of gastropods. If so, expand the voucher program to include those organisms.

**Complete the comprehensive survey for freshwater mussels.**
Future efforts will focus on filling gaps in distribution information, initiating comprehensive drainage surveys, maintaining Department records, and expanding specimen collections.

**Follow up on recommendations from the graduate research project on gastropods.**
The WGFD-funded graduate project at the University of Wyoming will provide direction for sampling methods. Those recommendations should be followed, and

baseline gastropods surveys should be conducted in the Yellowstone River basin.

**Increase connectivity where appropriate.** Investigate potential barriers in the Little Powder River identified by McGree et al (2010) and work with landowners to remove barriers.

Remove barriers to provide connectivity within the Greybull River, Shoshone River, and Nowood River drainages.

Implement screening solutions for diversions that entrain SGCN.

Continue collecting physical measurements and logging locations of natural and manmade barriers.

Continue developing an existing WGFD database to store physical measurements at barriers and barrier locations. Create an inter-agency vehicle for broad access and use of the database for visualizing and prioritizing the benefits of improving passage at alternative locations.

## Monitoring

**Establish standardized monitoring protocols and locations for native SGCN.** Monitor migratory fish use of the Kendrick Dam fish bypass channel on Clear Creek near the dam and upstream near Leiter, Wyoming to evaluate the ability of the bypass channel to pass species of interest.

Monitor newly established and/or expanded Yellowstone cutthroat trout populations.

Monitor sauger populations in the Bighorn/ Wind River drainage, including Boysen Reservoir, Bighorn River and Big Horn Lake.

Monitor burbot populations in the Bighorn/ Wind River drainage, including Boysen Reservoir, Big Horn, Trail, Ring, and Torrey lakes.

Re-survey a set of randomly selected sites from the Bighorn warm-water stream project (Bear 2009) to monitor species presence and relative abundance in the Nowood River.

Monitor water quantity and temperature in areas containing important native SGCN populations.

Monitor the establishment and spread of invasive species.

## Literature Cited

ABELL, R. AND 27 OTHER AUTHORS. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58(5):403–414.

ABRAHAMSE, M. S. 2008. Abundance and structure of burbot *Lota lota* populations in lakes and reservoirs in the Wind River drainage, Wyoming. Master's thesis. University of Wyoming, Laramie.

AMADIO, C. 2003. Factors affecting the distribution and life history of sauger in the Wind River watershed upstream from Boysen Reservoir. Master's Thesis. University of Wyoming, Laramie.

ANNEAR, T. C. 1992. Shovelnose sturgeon investigations; summary report 1983 to 1991. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.

BAILEY, R. G. 1995. Descriptions of the ecoregions of the United States. US Forest Service. Miscellaneous Publication No. 1391.

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.

BARRINEAU, C., B. BEAR, AND L. TOOKER. 2007. Status of habitat and native species in Northeast Wyoming prairie streams. Wyoming Game and Fish Department, Cheyenne.

BAXTER, G. T. AND M. D. STONE. 1995. Wyoming Fishes. Wyoming Game and Fish Department Bulletin Number 4. Cheyenne.

BAXTER, G. T., AND J. R. SIMON. 1970. Wyoming Fishes. Wyoming Game and Fish Department Bulletin Number 4. Cheyenne.

BEAR, B. 2006. Prioritization of eastern Wyoming prairie streams for conservation. Wyoming Game and Fish Department, Cheyenne.

BEAR, B. 2009. Warmwater fish and habitat surveys in the Bighorn River drainage, Wyoming. Wyoming

Game and Fish Department Administrative Report, Cheyenne.

BEETLE, D. E. 1989. Checklist of recent Mollusca of Wyoming. Great Basin Naturalist 49(4):637–645.

BENSON, A. J. 2009. Zebra mussel sightings distribution. Retrieved April 17, 2009 from http://nas.er.usgs.gov/taxgroup/mollusks/zebra mussel/zebramusseldistribution.asp.

BOURKE, J. G. 1891. On the border with Crook. Charles Scribner's Sons, New York.

BRADSHAW, W. H., D. J. ZAFFT, AND K. R. GELWICKS. 2008. Yellowstone cutthroat trout status and management in the Little Bighorn River, Tongue River, and Goose Creek drainages, Bighorn Mountains, Wyoming. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.

BURCKHARDT, J. 2009. Yellowstone cutthroat trout distribution and habitat conditions of the Yellowstone River drainage, Bridger Teton National Forest. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.

BUREAU OF LAND MANAGEMENT. 1990. Record of decision and approved resource management plan for Cody resource area. Accessed August 8, 2010, at http://www.blm.gov/pgdata/etc/medialib/blm/wy/programs/planning/rmps.Par.40097.File.dat/cyfo-rmp.pdf.

BUREAU OF LAND MANAGEMENT. 2001. Approved Resource Management Plan for Public Lands Administered by the Bureau of Land Management Buffalo Field Office. 2001. Accessed August 8, 2010, at http://www.blm.gov/pgdata/etc/medialib/blm/wy/programs/planning/rmps.Par.94672.File.dat/2001rmp_update.pdf.

CHAPMAN, S. S., S. A. BRYCE, J. M. OMERNIK, D. G. DESPAIN, J. ZUMBERGE, AND M. CONRAD. 2004. Ecoregions of Wyoming (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,400,000).

CLARK, M. L. AND J. P. MASON. 2007. Water quality characteristics for sites in the Tongue, Powder, Cheyenne, and Belle Fourche drainage basins, Wyoming and Montana, water years 2001–2005, with temporal patterns of selected water quality data. U.S. Geological Survey Scientific Investigations Report 2007–5146.

COMER, P., D. FABER-LANGENDOEN, R. EVANS, S. GALWER, C. JOSSE, G. KITTEL, S. MENARD, M. PYNE, M. REID, K. SCHULZ, K. SNOW, AND J. TEAGUE. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial systems. NatureServe, Arlington, Virginia.

CONNELL, K. 1980. Programmed creel census on Trail, Ring and Torrey Lakes, May 1–September 13, 1978. Wyoming Game and Fish Department Administrative Report, Cheyenne.

CONNELL, K. 1982. Boysen Reservoir creel survey. Wyoming Game and Fish Department Administrative Report, Cheyenne.

CONNELL, K. 1986. Wind River Section I programmed creel survey, 1985. Wyoming Game and Fish Department Administrative Report, Cheyenne.

CUMMINGS, K. S., AND C. A. MAYER. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manual 5.

CURTIS, J. AND K. GRIMES. 2004. Wyoming Climate Atlas. http://www.wrds.uwyo.edu/sco/climateatlas/toc.html

DAVIS, W. N. 2008. Effects of coalbed natural gas development on fish assemblages in tributary streams in the Powder River basin, Montana and Wyoming. Master's Thesis. Montana State University, Bozeman.

DORN, R. D. 1986. The Wyoming landscape, 1805–1878. Mountain West Publishing, Cheyenne.

EISERMAN, F. M. 1962. A fisheries survey of the lakes and streams in the Powder River drainage. Fisheries Technical Report Number 10. Wyoming Game and Fish Department, Cheyenne.

EVERMAN, B. W. AND U. O. COX. 1896. A report upon the fishes of the Missouri River basin. Report of the U.S. Commissioner of Fish and Fisheries for 1894:325–429. Government Printing Office, Washington, D.C.

FACIANNI, S. 1973. An evaluation of two years of carp and sucker removal at Ocean Lake. Wyoming Game and Fish Department Administrative Report, Cheyenne.

GUNDERSON, J. L., AND R. E. KINNUNEN. Editors. 2001. Sea grant aquatic nuisance species. Hazard analysis and critical control point training curriculum. Minnesota Sea Grant Publication Number: MNSG-F11, Minnesota Sea Grant, 2305 E 5th Street, Duluth, Minnesota.

HENDERSON, J. 1924. Mollusca of Colorado, Utah, Montana, Idaho and Wyoming. University of Colorado Studies 13:65–223.

HIGGINS, J. V., M. T. BRYER, M. L. KHOURY, T. W. FITZHUGH. 2005. A freshwater classification approach for biodiversity conservation planning. Conservation Biology 19:432–445.

HOKE, E. 1979. Wyoming mussel distributions as revealed by survey activities conducted during the summer of 1978. Wyoming Game and Fish Department, Cheyenne, WY.

HOLTON, G. D. AND H. E. JOHNSON. 1996. A field guide to Montana fishes. Montana Fish, Wildlife and Parks, Helena.

HOVINGH, P. 2004. Intermountain freshwater mollusks, USA (Margaritifera, Anodonta, Gonidea, Valvata, Ferrissia): geography, conservation, and fish management implications. Monographs of the Western North American Naturalist 2:109-135.

HUBERT, W. A. 1988. Survey of Wyoming crayfishes. Great Basin Naturalist 48:370-372.

HUBERT, W. A. 2010. Survey of Wyoming crayfishes: 2007–2009. US Geological Survey Report to the Wyoming Game and Fish Department, Cheyenne, WY.

JACOBS, J. J. AND D. J. BROSZ. 2000. Wyoming's water resources. University of Wyoming Cooperative Extension Service B-969R.

KENT, R. 1975a. Fish populations in tributaries to the upper Nowood Creek and evaluation of Yellowstone cutthroat trout planted in Little Canyon Creek. Wyoming Game and Fish Department Administrative Report, Cheyenne.

KENT, R. 1975b. Evaluation of Yellowstone cutthroat trout stocked in Rock Creek, Hot Springs County. Wyoming Game and Fish Department Administrative Report, Cheyenne.

KENT, R. 1977. Physical, chemical and biological investigations of Big Horn Reservoir 1965 through 1975. Wyoming Game and Fish Department Administrative Report, Cheyenne.

KENT, R. 1984. Fisheries management investigations in the Upper Shoshone River drainage, 1978–1982. Wyoming Game and Fish Department Administrative Report, Cheyenne.

KENT, R. 1995. Fisheries management perspective on public comments about the Buffalo Bill Reservoir and North Fork Shoshone River fisheries. Wyoming Game and Fish Department Administrative Report, Cheyenne.

KRUEGER, K. 1996. Assessment of lentic sport fisheries for burbot and sauger in the Bighorn/Wind River drainage, Wyoming. Master's Thesis. University of Wyoming, Laramie.

KRUSE, C. G. 1995. Genetic purity, habitat and population characteristics of Yellowstone cutthroat trout in the Greybull River drainage, Wyoming. Master's Thesis. University of Wyoming, Laramie.

KRUSE, C. G. 1998. Influence of nonnative trout and geomorphology on distributions of indigenous trout in the Yellowstone River drainage, Wyoming. Doctoral dissertation. University of Wyoming, Laramie.

KUHN, K. M. 2005. Seasonal movements and habitat use of adult saugers in the Little Wind River drainage, Wyoming. Master's Thesis. University of Wyoming, Laramie.

LAGESON, D. R. AND D. R. SPEARING. 1988. Roadside geology of Wyoming. Missoula, Montana, Mountain Press Publishing Company.

LIONBERGER, P. 2006. Juvenile sauger and fish assemblages in the Wind River watershed and Boysen Reservoir, Wyoming. Master's Thesis. University of Wyoming, Laramie.

MARSTON, R. A. AND J. E. ANDERSON. 1991. Watersheds and vegetation of the Greater Yellowstone Ecosystem. Conservation Biology 5:338–346.

MAY, B. E., W. URIE, AND B. B. SHEPARD. 2003. Range-wide status of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*): 2001. USDA Forest Service, Gallatin National Forest, Bozeman, MT.

MAY, B., S. E. ALBEKE, AND T. HORTON. 2007. Range-wide status of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*): 2006. Yellowstone Cutthroat Trout Conservation Team Report. Montana Fish, Wildlife and Parks, Helena, MT.

MCGREE, M. M., C. A. MOAN, A. LICKTEIG, AND G. P. EDWARDS. 2010. In Draft. Prairie stream fish communities and habitat associations in the Belle Fourche, Cheyenne, Little Missouri, and Little Powder river drainages of Wyoming. Wyoming Game and Fish Department, Cheyenne, WY.

MESSAMER, R. 1984. Yellowstone cutthroat culture in Wyoming: a progress report. Wyoming Game and Fish Department Administrative Report, Cheyenne.

MILLER, K. A. 2003. Peak-flow characteristics of Wyoming streams. U.S. Department of Interior, U.S. Geological Survey. Water-Resources Investigation Report 03-4107.

MOU (Memorandum of Understanding). 2000. Memorandum of agreement for conservation and management of Yellowstone cutthroat trout (Oncorhynchus clarkii bouvieri) among Montana, Idaho, Wyoming, Nevada, Utah, U.S. Forest Service, Yellowstone National Park, and Grand Teton National Park. Wyoming Game and Fish Department, Cheyenne.

NATURESERVE. 2009. NatureServe Explorer: An online encyclopedia of life Arlington, VA. Available http://www.natureserve.org/explorer.

NORTHWEST GAP ANALYSIS PROJECT. 2010. http://gap.uidaho.edu/index.php/gap-home/Northwest-GAP accessed July 2, 2010.

PATTON, T. M. 1997. Distribution and status of fishes in the Missouri River drainage in Wyoming: implications for identifying conservation areas. Doctoral dissertation. University of Wyoming, Laramie.

PATTON, T. M. 2001. Application of a modified index of centers of density to four drainages within the Missouri River Drainage, Wyoming. Wyoming Game and Fish Department, Cheyenne, WY.

PATTON, T. M., F. J. RAHEL, AND W. A. HUBERT. 1998. Using historical data to assess changes in Wyoming's fish fauna. Conservation Biology 12:1120–1128.

PATTON, T. M., W. A. HUBERT, AND F. J. RAHEL. 1995. Ichthyofauna in streams of the Missouri River drainage, Wyoming. Prairie Naturalist 30: 9–21.

PETERSON, D. A., P. R. WRIGHT, G. P. EDWARDS, J. R. HARGETT, E. G. FELDMAN, D. L. ZUMBERGE, AND P. DEY. 2009. Ecological assessment of streams in the Powder River structural basin, Wyoming and Montana, 2005–06. U.S. Geological Survey Scientific Investigations Report 2009–5023.

POWDER/TONGUE RIVER BASIN WATER PLAN. 2002. Final report prepared for the Wyoming Water Development Commission.

QUIST, M. C., W. A. HUBERT, AND F. J. RAHEL. 2004. Warmwater stream assessment manual. Wyoming Game and Fish Department, Cheyenne, WY.

RANGE-WIDE YCT CONSERVATION TEAM. 2009. Conservation agreement for Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) in the States of Idaho, Montana, Nevada, Utah and Wyoming. Montana Fish, Wildlife & Parks.

RAYNOLDS, W. F. 1868. Report on the exploration of the Yellowstone River. BiblioBazaar, LLC., Charleston, SC.

ROBERTS, E. L., M. T. WELKER, AND L. STAHL. 2003. Spawning habitat requirements and spawning behavior for Big Horn River sauger. Wyoming Game and Fish Department Administrative Report, Cheyenne.

ROTH, S. 2000. Wind River fishery evaluation 1994–1999. Wyoming Game and Fish Department Administrative Report, Cheyenne.

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 27:330-338.

SHOSHONE NATIONAL FOREST. 2009. Forest plan monitoring report for fiscal year 2008. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region.

SIMON, J. R. 1951. Wyoming fishes. Wyoming Game and Fish Department Bulletin Number 4. Cheyenne.

SMITH, M. 2008a. Use of the lower Greybull River by large bodied–large river fishes. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.

SMITH, M. 2008b. Fish entrainment in Harmony Ditch. Wyoming Game and Fish Department Administrative Report, Cheyenne.

SMITH, M. 2008c. Fish entrainment in the Cody Canal. Wyoming Game and Fish Department Administrative Report, Cheyenne.

SMITH, M. 2009. Fish entrainment in the North Fork Ditch, North Fork Shoshone River. Wyoming Game and Fish Department Administrative Report, Cheyenne.

STONE, M. D. 1995. Fish stocking programs in Wyoming: a balanced perspective. American Fisheries Society Symposium 15:47–51.

STRAYER, D. L. 2008. Freshwater mussel ecology. University of California Press, Los Angeles.

TURNER, W. 2007. Survey of herpefauna in the Powder River basin. Report to the U.S. Environmental Protection Agency. Wyoming Game and Fish Department, Cheyenne.

WELKER, M. T., E. L. ROBERTS, L. K. STAHL, AND J. WENDEL. 2002. Seasonal habitat use and habitat preference for sauger in the Big Horn River, Wyoming. Wyoming Game and Fish Department Administrative Report, Cheyenne.

WGFD. 1997. Statewide instream flow progress report, July 1996 to December 1996 In Annual fisheries progress report on the 1997 work schedule. Wyoming Game and Fish Department, Cheyenne.

WGFD. 1999. Annual fisheries progress report on the 1999 work schedule. Wyoming Game and Fish Department, Cheyenne.

WGFD. 2004. Annual fisheries progress report on the 2004 work schedule. Wyoming Game and Fish Department, Cheyenne.

WGFD. 2005. Annual fisheries progress report on the 2005 work schedule. Wyoming Game and Fish Department, Cheyenne.

WGFD. 2006. Annual fisheries progress report on the 2005 work schedule. Wyoming Game and Fish Department, Cheyenne.

WGFD. April 2010. 2009 Annual report strategic habitat plan accomplishments. Wyoming Game and Fish Department, Cheyenne, WY.

WHALEY, R., J. BAUGHMAN, K. JOHNSON, C. VIOX, AND K. CONNELL. 1979. Boysen Reservoir fish populations, status investigation. Wyoming Game and Fish Department Administrative Report, Cheyenne.

WILEY, R. W. 1995. A common sense protocol for the use of hatchery-reared trout. American Fisheries Society Symposium 15:465–471.

WILHITE, J. W. 2007. Use of infrared aerial photographs to identify and assess habitat needed by native fish in rivers. Master's Thesis. University of Wyoming, Laramie.

WIND/BIGHORN BASIN WATER PLAN. 2003. Final report prepared for the Wyoming Water Development Commission.

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY. 2001. Wyoming surface water classification list—Water Quality Division, Surface Water Standards: Wyoming Department of Environmental Quality, June 21, 2001, accessed July 21, 2010, at http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/2-3648-doc.pdf

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY. 2010. Wyoming water quality assessment and impaired waters list (2010 Integrated 305(b) and 303(d) Report). Wyoming Department of Environmental Quality Document #10-0230.

WYOMING GAME AND FISH COMMISSION. 1998. Fish stocking policy. Cheyenne, WY.

WYOMING GAME AND FISH COMMISSION. 2003. Chapter 10: regulation for importation, possession, confinement, transportation, sale and disposition of live wildlife. Cheyenne, WY.

WYOMING GAME AND FISH COMMISSION. 2005a. Chapter 33: Issuance of scientific research, educational or special purpose permits. Cheyenne, WY.

WYOMING GAME AND FISH COMMISSION. 2005b. Regulation governing private fish stocking. Cheyenne, WY.

WYOMING GAME AND FISH COMMISSION. 2008. Mitigation policy. Cheyenne, WY.

WYOMING GAME AND FISH COMMISSION. 2009. Strategic habitat plan. Cheyenne, WY.

WYOMING STATE GEOLOGICAL SURVEY. Major rivers of Wyoming. Accessed August 2, 2010 at http://www.wsgs.uwyo.edu/topics/waterresources/ .

ZAFFT, D. J. AND E. A. BEAR. 2009. Guidelines for the collection of fish voucher specimens. Wyoming Game and Fish Department Administrative Report, Cheyenne, WY.